Iron and Steel Engineer

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J. F. KELLY, *Editor*

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Coming Meetings and Papers

Association of Iron and Steel Electrical Engineers Convention and Iron and Steel Exposition

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PITTSBURGH SECTION
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JOINT MEETING OF A. I. & S. E. E. AND A. I. E. E. AT YOUNGSTOWN, OHIO. DEFINITE DATE AND PROGRAM TO BE ANNOUNCED LATER.

INSPECTION TRIP—CARNEGIE STEEL CO., McDONALD WORKS—DETAILS LATER.

PHILADELPHIA SECTION
APRIL 4, 1931

"GENERAL IDEAS AND DISCUSSION." Every Active Member is invited to prepare a short paper on a subject pertaining to the application of electricity to the iron and steel industry. Some of the papers to be presented are as follows:

"SERIES LIGHTING IN THE STEEL PLANT," by E. L. Anderson, Electrical Department, Bethlehem Steel Company, Sparrows Point, Md.

"FIRE HYDRANT," by George Pfeffer, Chief Electrician, Florence Pipe Foundry & Machine Company, Florence, N. J.

"AIR CONDITIONING EQUIPMENT," by Walter H. Burr, Superintendent, Electrical Department, Lukens Steel Company, Coatesville, Pa.

ALABAMA SECTION
MARCH 28, 1931

"LATEST DEVELOPMENTS IN UNIVERSAL PLATE MILLS," by E. S. Lammers, General Engineer, Westinghouse Electric and Manufacturing Company, Atlanta, Georgia.

CHICAGO SECTION
APRIL 8, 1931

Meeting will be on **"LIGHTING"** and will include a paper presented by the Lighting Institute and a trip through the Lighting Institute Exhibition in which various types of industrial lighting fixtures will be exhibited and demonstrated.

CLEVELAND SECTION
MARCH 27, 1931

"ARMOR CLAD SWITCH GEAR," by H. A. Nye, Engineer in Charge of Reyrolle Switch Gear Department, Allis Chalmers Mfg. Co., Milwaukee, Wis.

"APPLICATION OF RESEARCH TO THE DEVELOPMENT OF LOW VOLTAGE STEEL ENCLOSED SWITCH BOARDS," by Knute Falck, Engineering Department, I. T. E. Circuit Breaker Co., Philadelphia, Pa., Electric League Rooms, Builders Exchange Building, Cleveland, Ohio, at 8:00 P. M.

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It is at this point that the A. I. & S. E. E., founded in 1907, renders a real service to the Steel Mill Engineers. Through their sectional meetings, held in the steel mill centers of the United States—Pittsburgh, Chicago, Cleveland, Birmingham and Philadelphia, at which meetings engineering subjects of vital interest to our membership are discussed and through our official organ, the Iron and Steel Engineer, these papers and discussions are printed and distributed monthly to our membership. The Engineers themselves arrange the subjects that are to be discussed and are responsible for the editorial policy of our paper. Papers read before the Association are written from the Steel Mill angle; and every paper presented before the Association is directly applicable to the Industry. The material obtained through the Association could not be gathered for many times the sum of the yearly dues and in many cases could not be obtained through any other source.

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*Individual Drives for Table Rolls**

By W. B. SNYDER†

In this paper I will attempt to outline briefly the various mechanical arrangements used for the motors on individual table roll drives and to state some of the special electrical requirements of the motors, their control and power supply.

So far, all motors for individually driven rolls have been of the squirrel cage induction type. Quite frequently, entirely standard motors are used, connected to the rolls by flexible couplings. In other cases, the motors have special frames, with the bottom of the feet at the height of the shaft center line. This type is commonly used with double hotbeds, the motors being provided with oversized bearings and double shaft extensions, with the table rolls mounted directly on the motor shaft and supported on the motor bearings. A third arrangement utilizes motors without shafts or bearings, with the rotor overhung on the roll shaft and the stator supported on the table framework. This arrangement is frequently used by table manufacturers on tables with built-in motors. In still other cases, geared motors are used, either with gear boxes external to the motor or with gear reduction units built into the coupling end shields. Another type of motor which is rapidly growing in popularity is the Schloemann Engineering Company's Motor-Roller, of which I will have more to say later.

Nowadays all motors for individual table drives are equipped with anti-friction bearings. Ball bearings are used in case the motor bearings carry only the weight of the rotor, but in cases where the motor bearings carry all or part of the weight of the rolls, roller bearings are quite commonly used.

These motors are practically always totally enclosed, to protect them from water and mill dirt. Enclosing these motors imposes no hardship on the designer, as in the sizes usually involved, a totally enclosed motor can deliver its 40 deg. C. open rating continuously without exceeding 55 deg. C. rise.

Electrically, the motors depart from normal design in several respects. Since the torque requirements for starting the metal on the tables are materially greater than when the motors are running at constant speed, the motor squirrel cages are of the high resistance type, so that the maximum torque is developed at or near standstill. For direct connected drives, the speeds are usually low, requiring a large number of poles, with consequent poor power factor and efficiency. Furthermore, built-in motors which are furnished by the manufacturers without shafts or bearings must usually have abnormally large air gaps, which further reduce the motor power factor. Motors of this type require a high degree of mechanical accuracy in table construction as even though the air gaps are comparatively large, they are only of the order of 25 mils.

When the tables operate at constant speed, an attempt is made to use direct connected motors operating from the 220 volt, 3 phase, 25 cycle power usually available in steel mills. It is practically never feasible to operate direct connected table motors from 60 cycles, as the roll speeds require a number of poles far too large for economical design. Therefore, yhen only 60 cycle power is available, a frequency changer is installed and low frequency direct connected motors are used, or the motors are geared to the rolls.

When, as is most usual, speed adjustment is required, the table roll motors are supplied with power from an alternator driven by an adjustable speed direct current motor. The alternator is operated at constant field strength, thus developing a voltage directly proportional to its speed and frequency. As an induction motor excited from a voltage varying directly with the frequency operates at constant flux density, it will deliver approximately the same torque per ampere at any frequency, and thus may be given a constant torque rating over the desired speed range. The alternators are low power factor machines, usually about 50%, and consequently have a very high voltage regulation, of the order of 40% at normal load. During starting, the table motors may draw from three to five times normal current, and under this heavy low power factor overload, the alternator, if only normal field excitation were maintained, would drop its voltage to a value so low that the table motors could not start. Therefore, the alternator, which is usually excited from the 230 volt DC mill supply, is designed for normal excitation with about 160 volts across its fields. When the table motors are started, all or part of the permanent resistance in the alternator field is short circuited, greatly over-exciting the alternator and maintaining its voltage at nearly the normal value under starting conditions. This over-excitation is applied only long enough to permit the table motors to come up to full speed, and is then automatically removed to prevent over-heating the alternator fields. The same results could, of course, be accomplished by a voltage regulator, but the additional expense for the regulator and its necessary exciter is not usually justified as successful operation can normally be obtained by field forcing.

The control equipment for motors operating directly from the plant alternating current supply is very simple. A line contactor, or a set of forward and reverse contactors, controlled by a master switch is provided for each group of motors. Each motor group is usually supplied from two or more circuits, so that every other, or every third, motor is connected to the same circuit. Each circuit is provided with a lever switch for disconnecting purposes, so that for handling light material, only part of the table motors may be energized, with the others turning freely under the piece on the table. Overload protection is provided by a set of thermal cutouts in the circuit of each motor.

There are two general types of control used when power is supplied to the table motors from a motor-generator set, depending on whether all the motors

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†Industrial Engineering Dept., General Electric Company, Schenectady, N. Y.

supplied with the set are to operate together as a unit, or whether two or more tables are supplied from the same set. When all motors connected to one set are operated as a unit, the usual practice is to connect the motors to the alternator only through lever switches separating the various motor circuits without the use of circuit breaking devices. The table motors are started as a unit by applying field to the alternator and bringing the set up to speed. The motors and the set are controlled from a "start—stop" push button station or a master switch and when the starting indication is given, the driving motor starts and the field contactor and the field forcing contactor on the alternator panel automatically close. After the set has come up to speed, the field forcing contactor drops out, decreasing the alternator excitation to the normal value. When the stop button is pressed, the driving motor is disconnected from the line and brought to rest by dynamic braking, the table motors meanwhile being stopped by regenerative braking. When the set stops, the alternator field contactor opens, as the alternator field must be removed during periods of shutdown, to prevent overheating the field coils. In cases where emergency reversal is required, the direct current motor driving the set is provided with a reversing field switch.

The motor driving the motor-generator set is provided with the usual overload and undervoltage protection. Overload relays are also provided in the alternator circuit, and arranged to trip out the driving motor in case of overload.

When the motor-generator set supplies two or more table motor groups which must be operated independently, each group is provided with a set of contactors operated by a master switch. The motor-generator set is started as before, except that field forcing is not applied. In these cases, the field forcing contactor is arranged to close whenever any of the forward or reverse contactors controlling the groups of motors close, opening shortly thereafter under control of a timing relay. No circuit breaking devices are provided in the alternator circuit the overload relays on the alternator being arranged to open the table motor circuits.

To control the speed of the tables, the mill operator has control of the rheostat in the field of the direct current motor driving the alternator. The equipment is usually provided with a tachometer indicating roll speed. There are several methods of providing this speed indication, none of them being very accurate, but any of them being apparently satisfactory. The most usual method is to provide a tachometer generator mounted on the motor-generator set and to connect a voltmeter calibrated in RPM, or feet per minute of the table, to this generator. This is the equivalent of straight frequency indication on the alternator, and at times a frequency indicator calibrated in RPM is used in place of this equipment. Both methods are inaccurate, however, as they do not take into account the slip of the table motors, which may be of the order of 15% at the lower frequencies. A more accurate method is to connect a tachometer generator to a spare table motor, but in this case, the slip of the spare motor will be less than that of the motor driving the table under load. The most accurate method is to connect the tachometer generator to one of the motors on the table, but as this method exposes the tachometer generator to mill dirt and to mechanical injury, it is not usually used.

One disadvantage of the individual table roll drives is that the minimum speed for direct connected drives is pretty definitely limited to about 75 RPM, as the motors cannot be economically designed for more than 16 poles, and as below 10 cycles the size and cost of the adjustable frequency motor-generator set become excessive. Also, the torque of a motor with a large number of poles begins to fall off rapidly somewhere between 10 and 12 cycles, so that for low frequencies, abnormally large motors must be used. This rule is subject to exceptions, of course as some drives with 18 pole motors operating down to 8 cycles are installed. Furthermore, while this rule applies in general at present, the company with which the writer is associated is now developing an asynchronous alternator that can be built economically for extremely low frequencies. This alternator, if applicable to table drives, will permit the use of motors with a small number of poles for low speed service, with consequent reduction in motor size and improvement in power factor. There are quite a few low speed drives operating with geared motors, but this type of drive does away with one of the chief advantages of individual table drives—namely, the elimination of gearing.

Up to a few years ago, it was the general belief that the application of induction motors to individually driven table rolls was limited only to tables handling light material and to those which normally operated with few or no reversals. There were several reasons for this belief. First, the only small induction motors available were of the same construction as those used for light general purpose work, and these were not felt suitable for heavy steel mill service. Second, the inertia of an induction motor is inherently high as compared to a direct current motor developing the same torque, so that more power is required for quick reversal. Third, with a squirrel cage induction motor, all the losses incident to acceleration are dissipated in the rotor, whereas with a direct current motor, these losses are dissipated in an external resistor. However, with the advent of the motor roller the field of individual table drives has been greatly extended, and we must give the Schloemann Engineering Company credit for pioneering in applying their motor rollers successfully in places where most of us were certain they would not work.

The motor roller is an induction motor with the primary winding and core assembled on a stationary shaft and with the squirrel cage winding and core external to the primary and pressed in a shell which is supported on the shaft by ball or roller bearings. This shell serves as the table roller, its outer surface carrying the metal on the table. The motor leads are brought out through a hole in the shaft to a terminal box mounted on the end of the shaft extension. In addition to the advantages common to other types of individual table drives, namely, the elimination of gears and line shafts, with consequent

reduced maintenance and decreased table weight, the motor roller possesses features not found in other types. First, the motor roller is complete with its own bearings and requires no lining up. This makes installation very easy, as it is only necessary to clamp down the extensions of the stationary shaft in dead-eyes on the table frame and to connect up the leads. Second, the motor is totally enclosed within the rolls, and is thus protected from mechanical injury and dirt. The construction is very rugged, corresponding much more closely to steel mill practice than a general purpose motor does. There are no projections on either side of the table, which permits the piece to overhang the table on both sides. In one case, 110" plates are being handled by 48" rollers. The motor roller often permits a very simple table construction. For instance, a table for handling light material may be made of two channels with the dead-eyes supporting the motor rollers mounted on the underside of the bottom flanges, and with the channels serving as the side guards. The advantages of the motor roller in reducing the weight and mechanical complications of tilting tables are obvious.

The most surprising thing about the motor roller is that the motor windings are not damaged by heat transferred from the hot metal on the table. Several years of experience with motor roller installations have given conclusive evidence that no trouble is to be expected on this score. Apparently, the heat insulation provided by the air gap and the good heat conductivity from the large stationary shaft to the table framework prevents any material increase in temperature rise in the motor winding due to conduction of heat from the metal on the table. Furthermore, the motor roller electrical elements which the General Electric Company has built and is now building for the Schloemann Engineering Company are all designed for a low temperature rise (35 to 45 deg. C.) and are insulated throughout with Class "B" insulation.

In this country motor rollers have been applied on practically all types of table drives, except blooming mill tables. We understand blooming mill motor rollers are in operation in Europe, and they are now being seriously considered for such drives here. They are now in successful operation on tube mill tables of all sorts, and on intermediate and runout tables on continuous sheet mills, bar mills, merchant mills, and structural mills. They have been successfully applied on shear tables, hot saw, and scale tables, which require much inching and reversing for accurate spotting of the piece. The tables of the new Strong Alloy Mill of the United States Aluminum Company at Alcoa, Tenn., will practically all be equipped with motor rollers, even including the tilting tables of the large 3-high mills. These rolls are approximately 14" in diameter and 12' long. Probably the installation on which the requirements are most severe is on the front and rear tables of a reversing universal slabbing mill where the rollers are called upon to handle slabs up to 8,000 lbs. weight and where frequent fast reversals are required.

Evidence of the increasing popularity of the motor roller is shown by the fact that although our Company has been making motors for individual table drives since 1909, and started the manufacture of the electrical parts of motor rollers in 1929, to date the motor rollers account for about 30% of the total number of units we have built.

Individual drives for table rolls now occupy such an accepted place in the industry that it behooves the manufacturers and the users to agree upon some common standards for them. In the first place, there should be a generally accepted method of rating. Obviously, it is a misnomer to call for a 1 HP, 100 to 300 RPM motor, when the motor will only develop this rating continuously at one speed. The logical rating is on the basis of continuous torque, which will be the same over the whole speed range. Furthermore, in many instances, the starting torque is more important than the running torque, as usually any motors which will develop enough torque to start the table with metal on the rolls will easily develop continuously sufficient torque to keep the table operating at full speed. In such cases, the starting torque requirements should also be specified.

A second point upon which standardization is needed is the ratio of voltage to frequency on adjustable speed drives. Just what this ratio is, is of no importance, provided the same ratio is accepted by all manufacturers, but there appears to be a growing tendency to rate all these motors on the basis of 220 volts at 25 cycles, with the voltage increasing or decreasing directly with the frequency from this value. This standardization must, of course, apply to the adjustable frequency motor-generator sets supplying power to the table drives, as well as to the table motors. This would be advantageous in that frequently one type of motor could be used as a spare for several tables which might operate at different speeds, but which required the same torque per motor. Also, one adjustable frequency motor-generator set might serve as a spare for several tables of different speed ranges.

The adoption of these standards will go a long way toward eliminating the mystery which now appears to surround the ratings of motors for individual table drives, and will operate to the advantage of both the user and the manufacturer of these drives.

Recent Trends in Individual A.C. Roll Table Drives†

By R. M. BAYLE*

The first commercial installation of A.C. direct connected individually driven rolls was made some 15 years ago at a plant in Steubenville, Ohio. The response to this new type of roll drive was very slow and we do not find many commercial applications until some seven years later. It is probable that productive requirements did not require any radical departure from the conventional single motor group drive at this time. During the past five years there has been a growing demand in certain classes of roll table drive for extreme flexibility and reliability of performance.

A.C. roll table drives may be roughly classified into three heads, namely, direct drives, geared types and self contained units. Each of these classifications may be sub-divided into constant and adjustable speed types, and for reversing and non-reversing service.

Let us first consider the direct connected A.C. drive. The earliest types made use of a standard induction motor flexibly coupled to a single roll. The motor had two bearings and the roll had two bearings, all being of the sleeve type. The first improvement was to eliminate some of these bearings. Very few of the modern installations make use of more than two bearings. Anti-friction bearings are used almost exclusively. Designs seem to have centered on two common types. For narrow lightweight rolls it is common practice to mount the roll directly on an extension of the motor shaft. Various modifications of the foot design have been used to improve the rigidity of the unit. Where the roll is so long or so heavy that motor mounting cannot be used the accepted practice is to mount the rotor of the motor on an extension of the roll shaft. Numerous designs have been used to support the stator of the motor. Most of these designs use some sort of a flange mounting supported by the roll table bearing housing. Some difficulties with this design are on record but in all cases the writer believes this can be traced to a faulty mechanical design. The inherent design of an induction motor makes it necessary to maintain a very small air gap between the stator and the rotor. The mechanical design for overhanging a stator must be such that this air gap is maintained during assembly and operation. A compromise in this design can be made by operating with slightly larger air gaps which results in a lower power factor. From the electrical manufacturers standpoint it is of course desirable to keep the air gap as near the normal value as possible. It is felt that with sufficient attention directed towards the mechanical design the frame support and shafts can be made rigid enough to meet these electrical limitations.

From the electrical standpoint there seems to be no limit to the upper range of mill delivery speeds. A recent survey of 15 different installations showed mill delivery speeds ranging between 300 and 2500 feet per minute. The direct connected drive does have a limitation on the lower delivery speeds. The low economical operating point, of course, depends on the speed range desired, the frequency of operation at this speed and the fixed and operating costs of the equipment required. In general, 300 feet per minute seems to be the dividing line. Pole combinations of 6 and 8 are the most common with those of 10, 12 and 14 ranking next. The performance of an induction motor is very poor in the small sizes with combinations above 10.

The minimum frequency for adjustable speed applications is in the neighborhood of 8 cycles. Frequencies in this neighborhood require exceedingly large generators if any considerable power is required at this low operating range. Fortunately roll table applications are practically a constant torque drive which keeps the power requirements at the low speed at a minimum.

For the variable speed applications a range between 2 to 1 and 3 to 1 is usually satisfactory, and meets present day productive requirements. Four to 1 seems to be the desirable top limit but it is possible to extend this speed range. Economic limits rather than engineering limits will probably dictate the desired speed range.

A word as to the possibilities of reversing service with the A.C. drive. It is obvious that the individual A.C. drive has made large inroads in the field of the single direct current motor drive as applied to non-reversing, approach, transfer and delivery tables. With modern refinements of control it is also invading the reversing field of the direct current motor. This is only a natural progress. Direct current is expensive to produce as compared with alternating current and a direct current motor requires more maintenance than an alternating current motor. Granted that the auxiliary equipment can be kept at a minimum we have great possibilities in extending the field of individually driven A.C. reversing table drives. Installations of this type require a variable frequency motor generator set and individual roll motors suitably designed for the required starting torques. Early attempts to reverse at full frequency were unsatisfactory on account of the extremely large inrush taken at the point of reversal and the large sized equipment needed to handle the increased heating. It has been found that reversing at half frequency requires only about 25% of the heating capacity that reversing at full frequency does. The motor generator set is arranged to operate at a certain basic speed within the low frequency range. The roll motors are accelerated by forcing the field of the supply generator so that an increased torque is secured to bring the motors quickly to the low frequency speed. The driving motor of the supply motor generator set is then

†Presented before Pittsburgh District Section A. I. & S. E. E., October 23, 1930, Ambridge, Pa.

*General Engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

accelerated to the full frequency speed with the roll motors tied directly to the generator. During reversal the opposite takes place. The supply motor generator set is reduced to its base speed and the motors reversed or plugged to a stop at the low frequency.

It is difficult to say just where the economic line should be drawn between a direct connected individually driven reversing A.C. motor drive and a single motor group drive. It is a well known fact that the direct current motor is supreme in the field of exceedingly rapid reversals. When we get into the field where the number of reversals is limited and the time is not too short there are numerous applications where the A.C. drive will be superior when properly evaluated as to reliability, possible productive savings, first cost, maintenance and power costs. At the present time application data seems to indicate that the debatable range lies between a frequency of operation from 10 per minute down and a reversal time of 5 seconds up. A host of variables enter into this problem, such as the nature of the product, the speed variations of the schedules rolled, the length of the table and the frequency of operation.

Very recently A.C. drives of the individually geared type have been appearing on the market. The use of modern helical gearing totally enclosed and operating on anti-friction bearings has given the A.C. drive a notable extension in the low delivery speed ranges and the heavy duty torque requirements. With such a design it is possible to use a standard high frequency, high speed motor of small size and economical operating performance. Rotating inertia at the motor shaft is greatly reduced, making reversing service entirely practicable. In future years a great many applications will probably be made on heavy duty bloom and billet transfer tables and for slab runout tables.

Mechanical designs seem to be divided between those which makes the motor predominate and attaches the gear unit to the motor and those which makes the gear unit the basic part of the design and mounts the motor integral with it. Small units will naturally resolve themselves into the first class and heavier units into the second class. An interesting application was recently sold provided for a single 10 H.P. motor mounted integral with a gear case which supplies two separate rolls. By a slight modification of the design the rolls can be made parallel or at an angle, so that straightaway runs or turns can be made with practically the same unit. This application was made on a heavy duty slab runout table and gave a very close roll spacing with adequate drive unit spacings.

The third division of A.C. roll drives concerns self-contained units. There are two major types on the market today. The well known Schloemann roll is familiar to all. It consists of a stationary stator containing the primary winding and a rotor surrounding this stator. The outer periphery of the rotor is used as the roll surface. The second type is of an internal geared design. The roll is hollow and contains a small high speed induction motor connected by internal gears to the outer rotating cylinder. An inner stationary shell provides heat insulation and permits the internal gearing to be operated in oil.

Applications of self-contained units seem to be confined to places where space limitations are predominant. Where operations must be conducted from both sides of the roll this unit is ideal. An interesting application of the Schloemann roller was recently made on the pinch roll drive for a flying shear. It was desired to keep the top pinch roll as free from obstructions as possible and still synchronize it with the bottom pinch roll. The bottom pinch roll drive consisted of an adjustable speed direct current motor, an A.C. pilot generator and a speed indicating generator. The A.C. pilot generator was necessary for the speed regulating equipment, and in this case was made large enough to also supply the Schloemann roller used as the top pinch roll. In this way the two rolls were adequately synchronized without gearing and with the minimum of obstruction.

To summarize, the individually driven A.C. roll table is here to stay and is finding increased uses every day. Operating statistics indicate excellent reliability and efficient operation. With the active co-operation of plant operating engineers, mill builders and electrical manufacturers, the present economic limits should be rapidly extended.

Roll Table Drives †

By F. E. HARRELL*

By way of introduction, let us set forth two or three major assumptions in connection with roll table drives which it will be necessary for us to fully appreciate in order that we may proceed to a common understanding: It must be recognized that there is a wide variety of applications covered by run-out tables, even within a single mill; also, that the conditions surrounding the tables are so greatly diversified that they definitely impose certain requirements on the drive. For these reasons, we cannot pretend to set forth a single type of drive as the panacea of all ills in roll table drives.

Rather, each table must be considered separately and an attempt made to recommend the best all round drive which will most economically meet all of the customer's requirements. Nor do we feel embarrassed in subsequently recommending two different types of drive for similar conditions and application, for, as the art develops and we all obtain additional experience with such drives, we are very properly guided by those experiences. As a result, there is an ever changing trend in these recommendations to keep abreast of and capitalize upon our most recent findings.

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*Engineering Dept., Reliance Electric & Engineering Co. Cleveland, Ohio.

No attempt will here be made to justify individual drive as against group drive—the industry itself has been making that decision. We should recognize however that an occasional application even yet may best be made a group drive. Suffice it to say that individual drive has been very generally accepted in spite of—or perhaps on account of the marked change in the original conception of an individual drive, and that which we hold today.

Just a few short years ago the conventional individual drive leaned toward an overhung motor wherein the number of bearings for motor and roller were reduced from four to three or even two, thereby making the motors entirely special and fairly difficult of replacement, both from the standpoint of the supplier and from the standpoint of the mechanics of removing an overhung motor from the table.

More recently we have begun to appreciate the fact that we are not realizing the full benefits of individual drive unless we rather build or design the table around the motor, which in some cases can become the table itself. In other words, whereas we used to fit the motor to the mill, we now appreciate that all of the other equipment is special anyhow, so that if there is a possibility of modifying details of the other equipment to more readily accommodate a standard motor, that is the economically sound basis to proceed upon.

Let us stop here and point out some of the questions we wish to ask immediately upon coming to consideration of a new roll table drive.

"In what size and type of mill is the table to be?

What is the range, size and finish of material to be conveyed?

What is the roller spacing? Total length of table?

What is the weight of the mechanical roller? Solid or Hollow?

What are the conditions of heat, water and scale surrounding the table?

Will it be continuous running, or subject to a start-stop reverse duty cycle? If not continuous running, give exact duty cycle. (Number of reversals in stated interval, and time allowed for reversal).

Must the table start or stop under load? How quickly?

Will the table be constant or adjustable speed?

What will be the stock speed in feet per minute?

What is the stock speed of the mill pass or table adjacent?

Is it a straight runout or transfer table?

Will there be any idler rollers? If so, the number.

What is the power supply available?"

Having the answers to these and additional pertinent questions we may consider the general aspects of the application and decide between open, fully-enclosed, or fan-cooled motors. Having worked out the torque requirements and speeds, we may then decide between direct connection, gearing, pulley or flange mounting or other special type.

Feeling that it may be a matter of general interest to know what considerations enter into our calculation of torque requirements, let us set down here a possible example: viz.—

Roller spacing	3 feet
Material	¼"x30"x16 ft.
Roller diameter	11"
Maximum stock speed	800 FPM (278 RPM)
Table must start with material and accelerate in three seconds.	
Maximum weight per roller	80 lbs.
Weight of roller shell	230 lbs.

$$F = MA$$

$$F = \frac{W}{g} \times \frac{FPM}{60 \times \text{sec. to accelerate}}$$

$$F = \frac{310}{32.16} \times \frac{800}{60 \times 3} = 43 \text{ lbs. at surface of roller}$$

43 lbs. at 11" diameter equals 19.7 lbs. feet starting torque.

Using the factor of 1.5, in this case, to allow for possible friction load and extreme conditions, we get 1.5x19.7=29.6 lbs. feet as the starting torque we should require to meet the conditions outlined above.

It is of course possible to calculate to a finer degree of accuracy than outlined above, but in general, the above method with a factor of 1.5 to 2, depending on mill conditions, has seemed entirely adequate.

To develop this assumed case further, let us say that this is a constant speed table and other considerations lead us to favor a 3:1 single gear reduction which at once gives us a 3:1 advantage in torque, so the torque required of the motor is 29.6 divided by 3 or 9.86 lbs. feet.

Using an eight pole motor at 900 RPM synchronous speed gives us 300 RPM synchronous speed at the roller, so that under load we would likely get slip to bring us down to 825 feet per minute stock speed.

We must then select a motor capable of delivering 10 lbs. feet starting torque with an eight pole winding, and that motor is almost certain to have sufficient continuous capacity to transport the material. We would then give the motor whatever horsepower rating it was capable of taking for the 40° rise, if an open motor, or 55° rise if a fan-cooled motor. If the motor is to be fully-enclosed, then the rating becomes a serious consideration and may require an increased frame size.

This has led us to the point where I should like to recall and again point out the fallacy of specifying horsepowers for runout table motors. In about ninety nine cases out of one hundred the application is such that any motor which will start the load will carry it without a question, since of course the work of maintaining a given velocity of a given mass is relatively small as compared to the work of originally bringing the given mass to the given velocity.

The particular point is this. There are frequently roll table drives with more or less severe demands in the way of torque at starting, which we can obtain in either of two ways:—first, by increasing standard motor size to get the desired torque; second, to obtain a greater torque from a given motor size by introducing a high torque or high resistance rotor. The latter of the two methods is invariably the most economical and satisfactory, but all too frequently the purchaser goes ahead to specify a horsepower requirement which is based upon synchronous speed and starting torque. The result is that the smaller motor with the high torque rotor

will not carry the stated horsepower continuously without overheating due to the great slip introduced by the high resistance rotor. Considering the application, however, the high torque motor would carry continuously the load actually imposed under the running condition, and would accelerate the material to the given speed even more quickly than the standard motor.

The speaker recalls having heard this matter of torque referred to the Standards Committee of the A. I. & S. E. E. at the June 1928, Chicago Convention although I personally never learned of the report of your committee on this matter. It is indeed a matter worthy of your further consideration for the sake of the industry.

Before leaving entirely the theoretical considerations, we should point out the difficulty in adjustable speed drives, where a motor driven alternator supplies power for the motors, in obtaining a frequent, rapid reversal, without definitely increasing the capacity of the alternator. Speaking for my own company, we calculate an alternator for such a reversing job on the basis of the locked current of the total number of motors to be reversed at one time, together with any additional current for such motors as may be left running on during the time of reversal of the balance. Roughly, the increase in alternator size to accommodate reversal may be from 25% to 100% more than required for otherwise normal operation.

The voltage regulation of such alternators is the vital thing, and is the reason for requiring an oversize alternator for reversing duty, in order to reduce the voltage drop under peak current to a minimum. For this reason we prefer plugging the motors rather than reversing the alternator field. Consideration of a relay to provide over-excitation of the alternator field during reversal is suggested. We have found it beneficial.

May we now turn to a discussion of the various types of individual motor drive as supplied to typical applications.

Referring first to the direct connected types, the overhung motor hereinbefore mentioned, was always fully-enclosed because of its necessary location on the end of the roller. They have been used in the past for various tables but mechanical difficulties in alignment over a period of time, inaccessibility, and the fact that each job is a special motor, all have combined to a certain extent to cause the overhung motor to gradually drop out of the picture.

The direct coupled motor drive is proving very popular for certain applications for various reasons. First, it can nearly always be a standard motor mechanically. It can be removed without disturbing alignment of the rollers. In general, provided the speed required can be obtained from the mill frequency and motor poles up to sixteen, the direct connected motor is to be favored for the average application. This is also especially desirable for tables requiring frequent reversal or rapid acceleration, due to the absence of any intermediate unit. It has actually proven out in some cases also, where reversal was a feature, that the ten or twelve pole motors for direct connection would require a lesser total locked KVA input than the alternative four pole motor with a suitable speed reduction unit, due to the inherent characteristics electrically of ten and four pole motors respectively.

Likewise it is not infrequently more economical to use an eight or ten pole motor direct connected than to use a four pole motor with a reduction gear.

Protection for the direct connected motor may occasion the use of a fan cooled construction if the surrounding air is not too hot, or fully enclosed. It is my opinion that couplings suitable for insulating the motor end from the heat of the roller are entirely feasible and practicable.

Definite actual installations of this type occur to the speaker in an adjustable speed Merchant Mill table for conveying hot bar and rim stock over a 2:1 speed range, operating from a motor-alternator set at from 15 to 30 cycles. Another operating in a strip mill over a 2:1 range up to 11 FPM operates from an alternator which in turn is driven by belt from the main motor driving the last pass ahead of the table to which delivery is made. Both of these happen to be standard open motors.

Another type of direct connected motor is the so called pulley type, wherein a pulley or roller is mounted directly on the motor shaft or even more frequently, two pulleys on double end shaft extensions. Such motors are always fully enclosed due to their size and location. Most often such drives are used for relatively high speed Merchant Mills and more specially for hot bed center tables. This type tends to simplify the mill table construction, but of course makes the motor inaccessible of itself unless production is interrupted.

One such application occurring to me is a single pulley type on an 8" Merchant Mill hot bed for handling hot material at about 2000 FPM. These motors were fully enclosed and insulated with Class B insulation—mica and asbestos.

Geared drives may be of two general classes, one where the gearing is a separate reduction unit, and the other where the motor carries a pinion engaging an internal ring gear in the end of the roller.

The internal gear drive is especially suited to small reduction ratios. It is invaluable in the case of the applications requiring a double transfer of hot material since it permits lowering the motor with respect to the centerline of the shaft. It not only gives mechanical clearance for the transfer mechanism but also leaves a valuable air space between the hot material and the motor—forming the best kind of natural protection from reflected and radiated heat.

The internal gear construction making use of a perfectly standard motor is doubtless the most economical construction available in individual drives. Its use however is limited as indicated above. Such a drive to the speaker's knowledge has long been operating on a table conveying hot billets from the furnace around a corner table to the mill.

The separate reduction unit is required for larger reductions than could be obtained with the single internal gear type. The other advantages peculiar to the internal gear type apply equally well here with the possible exception of the amount of clearance available for transfer or kick-off, not to mention air pocket insulation for the heat from the material. In addition to the foregoing there is the added advantage of being able to set a standard motor at right angles to the table with the consequent saving of lateral space adjacent to the table. In this con-

nection we might report that installations of several hundred such rollers are working out quite satisfactorily in tube mills with right angle worm gear reducers. Another item of interest in these particular applications is the surprising benefit to the cooling of the open motors applied there in erecting a thick asbestos shield, suitably backed with sheet steel, between the rollers and the motors.

Other interesting geared drives include one in a strip mill for handling the hot strip on a double transfer table at about 1200 FPM maximum speed down to half of that value. These motors were fully enclosed and used Class B insulation. Another installation handles large cold tubing at a constant speed, but inasmuch as the rollers must start with the pipe on them a high torque rotor is used.

Summarizing, we may say that in general the presence of scale and oxidation lead us to consideration of fan cooled motors which cost little more than open, relatively, and are interchangeable in dimensions with the open motor. Where the torque requirement is such as to lead to a large slow speed motor, larger than actually required to carry the load, there fully enclosure should be used.

Another consideration which strikes us favorably is the possibility of combining the lubrication of all motors in a given table in a one shot lubrication system. The motors are nearly always in such a position as to make lubrication difficult and it would seem reasonable to expect all the motors in a given table to require the same amount of lubricant. Discussion is invited on this point.

The present trend in individual drive as we sense it is to use the standard low cost squirrel cage motor in just so far as possible, which means a geared drive, readily accessible in the table, readily replacable by the manufacturer, facilitating service, repairs, and spare part protection since they are apt to be mechanical duplicates of the same size motors in other parts of your mill.

Drives for Roll Tables

Discussion

Discussed by

J. J. Booth, Electrical Superintendent, National Tube Company, Gary, Indiana.

G. R. Carroll, Electrical Superintendent, Jones and Laughlin Steel Corporation, Aliquippa, Pa.

K. Feller, Sales Manager, Schloemann Engineering Company, Pittsburgh, Pa.

L. A. Umansky, Industrial Engineering Department, General Electric Company, Schenectady, N. Y.

J. J. Booth: The Association of Iron and Steel Electrical Engineers are indeed very fortunate in having the opportunity of inspecting the new plant of the A. M. Byers Company, and I personally wish to express my appreciation of this privilege. It is an exceptionally well laid out plant, with ample space and having the idea of so-called straight line production. I wish also to express my appreciation of papers presented here this afternoon by Messrs. Snyder, Harrell and Bayle.

The subject of "Drives for Table Rolls" is today receiving a great deal of merited attention. Personally, I am not wedded to any particular type of drive. I feel that the general conditions and surroundings and material to be handled warrants a very careful study of methods of driving and the choice of the best method for the particular drive.

There is and has been quite a lot of comment on what is termed "unit drive system," which is driving several rollers from one motor. This type of table is exceptionally hard to maintain and keep in alignment. We who have operated this type of table for a number of years admit that if this type of table is not properly designed that there is a considerable amount of maintenance and exceptional friction load thrown on motor, and in many instances, motor is overloaded and burned out due to bearing trouble, gear and pinion trouble, etc. However, I believe there are still a number of applications where this table is justifiable, particularly in places where the billets or slabs to be handled are hot and heavy. In these applications, I believe that the use of antifriction bearings, helical gears and heavy table construction can make these tables very satisfactory and operate with a nominal amount of maintenance.

The application of small industrial type motors to roller drives through worm gears or spur gears in many instances seems to be very popular, especially from the standpoint of taking a motor away from the direct action of the heat from material being handled, and I think there are a number of applications on which one is justified in using this type of construction, depending in a large measure on the speed required of table.

As has been brought out this afternoon, the Schloemann motor roller has made quite an inovation in this country in the method and type of table drives. A great deal of credit is due Schloemann Engineering Co., along with the company which manufacture this type of equipment for them, for their pioneer work in this type of application. There is no doubt in the world but that there are many applications on which this type of drive is ideal. To my mind, there are also other applications on which one had better stick to heavier type of drive, particularly if the material to be handled is very heavy and of high temperature.

Relative to variable speed which may be obtained by the use of frequency changer sets with this type of equipment, I would suggest that if one deems it necessary to have variable speed he should give his frequency changer set very serious consideration, and make sure he has ample capacity, because without capacity to produce required torque, one is doomed for more or less grief. Another point is to make sure that the rollers are properly designed and that

the anti-friction bearings will take both thrust and severe abuse from billets and slabs falling on the rollers.

Relative to the question of torque rating and HP. rating on motor, I agree heartily with the men who have presented these papers this afternoon in the fact that we are very little interested in HP. rating of these rollers. It is imperative, however, that if the rollers do not have sufficient torque to start the dead weight and get the thing well in motion, they will not operate satisfactorily. But with sufficient torque to start the dead weight, there is very little trouble to be experienced.

Again I wish to state that I think we have had a very profitable day. We have seen the most modern steel plant in the country and have had an excellent symposium presented on the Application of Motors for Driving Roll Tables, all of which to my mind has been very helpful to the Association and to the individuals who have been fortunate enough to attend.

G. R. Carroll: We have quite an installation of the self contained type of motor rollers and have had some trouble, which can be divided into two classes.

First. Winding failure due to roasting. This trouble has been eliminated by using fire-proof insulation, which was not used exclusively in some of the first rollers installed. Where cold material was to be handled we compromised on cotton insulation on the first installations.

Second. Where the rollers are exposed to water considerable trouble has been experienced with sealing the rollers against water. In order to correct this condition, the manufacturer has developed a water seal, which consists of a leather packing ring and a grease gland. A special stiff grease is used. This gland is separated from the anti-friction bearing grease chamber. Very good results have been obtained with the newer development.

At first we were quite skeptical about using this type of roller in locations where hot material rested on the motor rollers for some time. After running tests with a water cooled shaft, it was found that the water could be dispensed with without internal temperatures becoming dangerous.

This type of roller unquestionably has a place in the steel mill, and I believe their use will continue to increase as we get more confidence in them.

K. Feller: I believe there is little that I could offer as an addition to the papers which were so ably presented and which cover the subject fully. However, I wish to say that I am glad to have had the opportunity to be here today and to hear of some actual operating experience on individually driven rollers. I feel more could be learned from those familiar with operating details and I wonder if Mr. Carroll, for instance, would not care to give us the benefit of some more of his experience?

L. A. Umansky: You probably remember the rather clever remark made by Mark Twain that "Everybody is talking about the weather but no one seems to do anything about it." It seems as if the same thing applies to the matter of standardization of the individual motors for mill tables. As early as June, 1928, I suggested at the Annual Convention of this Association, held at Chicago, that the Standardization Committee be instructed to adapt a standard whereby such motors be rated on a torque basis, and that the ratio of the voltage and frequency be definitely fixed. This suggestion has been approved by all present, and has been duly recorded in our Proceedings, (*) but nothing has ever come out of it.

It seems that it will be perfectly proper if this meeting will authorize our Chairman to instruct the Standardization Committee to take the necessary action and to bring about the much-talked of standardization along these lines. I move, therefore, that our Chairman be authorized to proceed accordingly.

My second remark will refer to the continuous rating that should be given to the individual motors. Opinion has been expressed today that the starting torque is the thing that should be built into the motors and, once this starting torque is provided, the motors will always have a sufficient continuous capacity. This may or may not be true, depending on the use which you intend to make of the motor driven rollers. Suppose a group of motors is subjected to a rather frequently repeated reversing cycle. The starting torque may be ample to accelerate each roller within the specified time, but the heating, due to the repeated cycle, may exceed the continuous capacity of the machine. To use the comparison which I have used once before, such a motor will be similar to a powerful automobile with an undersized radiator: The hill climbing ability is there, but the ability to repeat this performance continuously might be missing.

Some of the runout table motors are driving rollers located in front of the finishing stand. The operator is usually apt to set the table speed too high, with the result that the rollers will be rubbing against the bar, the tail end of which is still in the mill. It is true that the roller motors will slow down somewhat under such conditions, but this slowing down is contingent on taking more load; as the result, the heating of these motors will be far greater than may be estimated on a purely theoretical basis, without taking into account such intangible but existing factors.

The members of this Association will remember that several years ago a good deal of discussion was raised regarding the necessity of specifying the continuous rating of large reversing mill drives. Some opinions were expressed that the maximum torque is all that is required to determine the size of such a drive. Experience has proven the fallacy of such a statement and nowadays all reversing motors built in this country are provided with nameplates specifying not only the maximum torque, but the continuous capacity as well.

Under the circumstances I believe, and I strongly recommend that the Standardizing Committee attempt to standardize both the starting and continuous torques of the table motors.

In my third remark I want to point out the inherent limitations of the individually motor-driven rollers, and the danger of their mis-application. Frankly speaking, I am quite enthusiastic about the wide use which the motor driven rollers have gained within the recent years. Like most of other electrical engineers, I welcome their success, and for exactly the same reason I would not like to see their success marred by a faulty application.

(*) See Proceedings of the A. I. & S. E. E., 1928, Page 340.

For instance, I would be very reluctant to see these motors applied to such exacting duty as driving the live table rollers of a reversing blooming mill. In the first place, the individual motor driving a table roller is, after all is said and done, nothing but a squirrel cage induction motor. Just as "The leopard can not change his spots," so the induction motor can not change its torque-inertia and torque-speed characteristics, which are far inferior to those of a mill type DC motor. We would ordinarily object, and rightly so, to the use of an induction motor for driving a conventional live table through a set of gears and a line shaft; for a given starting torque, the WR^2 of a D.C. mill type motor is so much smaller than the WR^2 of an induction motor, that a D.C. equipped mill table will easily outrun and outmaneuver an A.C. mill table; in other words a D.C. drive for live tables will increase the mill tonnage while an A.C. drive would seriously hinder it. These facts are so well known to all of us that they may be merely mentioned.

Now, if we unanimously outrule a large induction motor for driving several rollers geared together, there is no good reason to expect a better performance if we substitute for it several smaller motors, each driving individually a table roller. In fact, such substitution in this case is apt to make the things worse, rather than better. If you consider a live table of a reversing blooming mill, you will readily see that at times the ingot is supported by only two table rollers. Therefore, the torque of only two small motors would be available to move the ingot to or from the mill; it would be unreasonable to expect a satisfactory operation under the circumstances. In case of a geared table, the whole torque of the large driving motor can be concentrated on the two rollers which are supporting the ingot.

I do not wish to state that it will be never possible to build a live table for a blooming mill with individual motors. The engineers should really discard the word "impossible" from their language. My point is simply that before this is successfully done, some radical invention must be made, changing the inherent shortcomings of the induction motors, as compared with the D.C. machines. I believe that then, and only then, this application will become an unqualified success. When this will be accomplished I will be the first one to take my hat off before the man who will accomplish this result.

Minutes of Committee Meetings

MINUTES OF MEETING, "SPECIAL COMMITTEE ON BEARINGS" ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS, HOTEL STATLER BUFFALO, N. Y.

Friday Morning, February 6, 1931

PRESENT

F. D. Egan, Chairman, Bethlehem Steel Company, Lackawanna, N. Y.

J. F. Kelly, Managing Director, A. I. & S. E. E., Pittsburgh, Pa.

H. R. Turner, Electrical Dept., Bethlehem Steel Co., Lackawanna, N. Y.

D. E. Batesole, Norma-Hoffman Bearings Corp., Stamford, Conn.

H. G. Wallace, SKF Industries Inc., Buffalo, N. Y.

S. R. Cox, Jr., Hyatt Roller Bearing Co., Pittsburgh, Pa.

J. M. Kelly, Hyatt Roller Bearing Co., Pittsburgh, Pa.

A. E. Fawley, Marlin Rockwell Corp., Plainville, Conn.

H. R. Reynolds, Fafnir Bearing Corp., New Britain, Conn.

F. H. Buhlman, Rollway Bearing Co., Inc., Syracuse, N. Y.

Samuel Farrell, Rollway Bearing Co., Inc., Pittsburgh, Pa.

F. Waldorf, Timken Roller Bearing Company, Pittsburgh, Pa.

J. R. Lewis, Crocker Wheeler Electric Mfg. Company, Pittsburgh Pa.

A. D. Brown, Allis Chalmers Mfg. Company, Buffalo, N .Y.

J. L. Brown, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

D. H. Schacht, Century Electric Company, Buffalo, N. Y.

V. J. Nolan, National Carbon Company, Pittsburgh, Pa.

A. A. Proudfoot, Reliance Electric & Eng. Co., Buffalo, N. Y.

C. C. McDowell, General Electric Company, Buffalo, N. Y.

C. W. Cristal, Crocker Wheeler Electric Mfg. Co., Buffalo, N. Y.

R. J. Harry, Alliance Machine Company, Alliance, Ohio.

E. Homer Kendall, Alliance Machine Company, Alliance, Ohio.

W. C. Heinle, Cleveland Crane & Engineering Company, Wickliffe, Ohio.

R. E. Ludwick, Cleveland Crane & Engineering Company, Wickliffe, Ohio.

H. W. Ball, Morgan Engineering Company, Alliance, Ohio.

G. R. Carroll, Jones & Laughlin Steel Corp., Aliquippa, Pa.

Chas. Johns, Buffalo Steel Company, Tonawanda, N. Y.

A. R. Cary, Buffalo Steel Company, Tonawanda, N. Y.

The Meeting was called to order by Mr. Egan, Chairman, who announced that the purpose of the Meeting was to reorganize the Committee and continue the work of collecting and tabulating data on the application of Anti-Friction bearings in the steel industries. He stated that a letter had been sent out through the A. I. & S. E. E. requesting opinions as to what should be the next problem for

the Committee to tackle and read a resume of replies to this inquiry.

Mr. Egan reviewed briefly, the data which has been published on Mill and General Purpose Motors and on crane and requested opinion of assembly as to whether there should be any corrections or additions to this data.

Mr. Brown of W. E. M. Company stated that they were furnishing in some instances, double row ball bearings on Mill motors and he felt that data covering this application shoul be included in the tabulation on Mill motors. The Westinghouse data on this subject was sent in too late for publication in the 1930 tabulation. Mr. Egan requested Mr. McDowell of General Electric Company and Mr. Lewis of Crocker Wheeler Company to send in their data on this Company's application of double row ball bearings to Mill motors which will be included in the tabulation under Mill Motors.

Mr. Brown of W. E. M. Company raised the question of speed limitation for the large size roller bearings on Mill motors. Most Mill type motors operate at relatively low speeds but this is not always the case. When the larger bearings operate at higher speeds, the heating sometimes becomes objectionable and stresses on retainers or other parts become so great as to tend toward early failure. Mr. Brown stated that the 318 or 319 bearing on frames MC-60 and MC-70 might be considered large in this sense, and he felt the question of maximum safe operating speed for bearings should be determined by Bearing Manufacturers. Mr. Brown pointed out that in some instances where bearing heating was encountered on operating roller bearing motors, the customer became concerned and motor builder is not in a position to advise what is safe temperature rise on bearings.

Mr. Brown stated the question of end thrust on roller bearing application to Mill Motors should be clarified inasmuch as this factor tends to increase heating in bearings. He pointed out that some types of Anti-Friction bearing depend on sliding friction to carry axial thrust and was of the opinion that these bearings would not handle satisfactorily, a continuous thrust set up when motors are mounted at an angle or drive through Helical gearing.

Mr. Egan, suggested, and it was decided, that W. E. M. Company, General Electric Company, and Crocker Wheeler Company should outline in a letter to him, information desired relative to operating conditions on speed, temperature and end thrust of roller bearing drives and this would be made up in the form of a circular and sent out through Mr. Kelly's office to operators in the field to develop more information on the matter.

Mr. Lewis of Crocker-Wheeler Company raised the question of using ball instead of Roller Bearings on Mill type motors operating at or above 1200 rpm. Mr. Egan advised that this is covered by placing the responsibility for determination of safe operating speed limits with the Roller Bearing Manufacturers. He suggested also, that practice will largely determine the application.

Under General Purpose Motors, Mr. Egan asked for an opinion from the Committee on tabulation of data on the new N.E.M.A. frames. Discussion on the subject, Messrs. Lewis, Brown and Egan brought out the fact that N.E.M.A. has a Committee who are studying bearing data and lubrication of these motors. Mr. Lewis was of the opinion that Messrs. McCutcheon of Reliance Engineering and Electric Company and Owen of Westinghouse Electric and Manufacturing Company were serving on the N.E.M.A. Committee and would possibly be in a position to give information on what has been done on the N.E.M.A. motors. (Neither Mr. McCutcheon nor Owen were present at the Meeting).

Under the subject, Anti-Friction bearing application on cranes, Mr. Egan advised that so far only bearings applied on bridge and trolley trackwheels had been tabulated. Mr. Harry stated that he was of the opinion that mountings particularly self-aligning bearings would be an important factor in successful application of Anti-Friction bearings on cranes. He, also, raised question of inconsistencies in comparative values for loadings in Bearing Manufacturer's catalogue ratings and stated that he was of the opinion that failure in many cases of bearing application was due to incorrect understanding of load ratings and without sufficient margin for safety.

Discussion: Mr. Heinle, Mr. Ball and Mr. Egan.

Mr. Heinle stated that he was of the opinion that correct application of bearings for loadings and safety factors rested with the experience of Crane Builders and that catalogue ratings do not mean much as regards application to trackwheel-bearings. Mr. Ball stated that he could obtain necessary information on correct bearing application from Bearing Manufacturers for a given wheel load and rpm.

Mr. Carroll of J. & L. Steel Corporation stated that they have had marked success with roller bearings on cranes, but has also had some failures from axial thrust.

It was decided to continue the tabulation of data on crane bearings with the Bearings pertaining to bridge drive shafting. Mr. Egan stated, he would prepare a sketch outlining data required and submit to Crane Builders for their recommendations and practices in Bearing application. It was pointed out that lineshaft diameter would determine bearing sizes and data for shafts ranging from 3⅜" to 5½" diameters would cover the field for Mill type cranes. Crane builders on receipt of sketch to forward their data to Mr. Egan for tabulation before next Meeting.

Meeting Adjourned

MINUTES OF MEETING, "SPECIAL COMMITTEE ON BEARINGS" ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS, HOTEL STATLER BUFFALO, N. Y.

Friday Afternoon, February 6, 1931

PRESENT

F. D. Egan, Chairman, Bethlehem Steel Company, Lackawanna, N. Y.

J. F. Kelly, Managing Director, A. I. & S. E. E., Pittsburgh, Pa.

H. R. Turner, Electrical Dept., Bethlehem Steel Co., Lackawanna, N. Y.

D. E. Batesole, Norma-Hoffman Bearings Corp., Stamford, Conn.

H. G. Wallace, SKF Industries Inc., Buffalo, N. Y.

A. E. Fawley, Marlin Rockwell Corp., Plainville, Conn.

H. R. Reynolds, Fafnir Bearing Corp., New Britain, Conn.

F. H. Buhlman, Rollway Bearing Co. Inc., Syracuse, N. Y.

Samuel Farrell, Rollway Bearing Co. Inc., Pittsburgh, Pa.

F. Waldorf, Timken Roller Bearing Company, Pittsburgh, Pa.

J. R. Lewis, Crocker Wheeler Electric Mfg. Company, Pittsburgh, Pa.

J. L. Brown, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

V. J. Nolan, National Carbon Company, Pittsburgh, Pa.

A. A. Proudfoot, Reliance Electric & Eng. Co., Buffalo, N. Y.

C. C. McDowell, General Electric Company, Buffalo, N. Y.

C. W. Cristal, Crocker Wheeler Electric Mfg. Co., Buffalo, N. Y.

R. J. Harry, Alliance Machine Company, Alliance, Ohio.

E. Homer Kendall, Alliance Machine Company, Alliance, Ohio.

W. C. Heinle, Cleveland Crane & Engineering Company, Wickliffe, Ohio.

R. E. Ludwick, Cleveland Crane & Engineering Company, Wickliffe, Ohio.

H. W. Ball, Morgan Engineering Company, Alliance, Ohio.

G. R. Carroll, Jones & Laughlin Steel Corp., Aliquippa, Pa.

Chas. Johns, Buffalo Steel Company, Tonawanda, N. Y.

A. R. Cary, Buffalo Steel Company, Tonawanda, N. Y.

Meeting was called to order by Mr. Egan, Chairman, who stated the purpose of the Meeting was for re-organization of personnel of Committee for consideration of application of Anti-Friction bearings on Roll Necks. He advised that very little had been done to date by the Committee in the way of collecting and tabulating data on this subject and it is in order for the Committee to decide from what angle the problem will be approached.

Discussion: Mr. Waldorf, relative to his experience in studying this application. He was of the opinion that correct determination of rolling pressures from test or calculation formed a basis for correct application of Anti-Friction bearings in this field. He suggested that considerable information has already been published in the way of technical papers on the subject and this information should be analyzed in connection with the Committee's investigation of the subject.

Discussion: Messrs. Waldorf, Buhlman and Egan on subject of Rolling pressures. Mr. Egan suggested problem of rolling pressures is largely problem to be solved by Bearing Manufacturers and the work of this Committee is more to collect and tabulate data on Mill Necks which have been equipped with Anti-Friction bearings.

Discussion: Mr. Waldorf relative to HP saving resulting from Anti-Friction bearing equipped Mills. He stated in some instances as much as 46% savings had been effected as indicated by test data.

Mr. Egan pointed out that the first step toward analyzing the Roll Neck problem was to organize the personnel of the Committee.

Mr. Waldorf suggested that considerable research work on this subject has been done by the following men and he was of the opinion that they should be invited to serve on the Special Committee on Bearings while considering the problem of Roll Necks. Prof. Trinks, Carnegie Institute of Technology, Mr. Kieft, Illinois Steel Company, Mr Gasche, Bethlehem Steel Company. Mr. Lewis suggested that one or two representatives from each of the leading Companies Manufacturing Mills should also be invited to serve on the Committee, as well as Anti-Friction Bearing Manufacturers interested in this type of Application and Steel Mill men who are using them.

Mr. Egan advised the Committee would be organized along this line suggested and through the co-operation of Mr. Kelly's office.

Mr. Egan requested Messrs. Waldorf, Buhlman, Batesole and Wallace and any other bearing Manufacturer who has bearings operating in Roll Neck service to forward any bearing data now available on Mills which they have equipped with anti-friction bearings and he will tabulate same and have something for the next Meeting. Bearing Men to send in data in about three weeks if possible.

It was decided to hold the next Meeting in Pittsburgh in the last part of March.

Meeting Adjourned.

MEETING OF CONTROL MANUFACTURER'S REPRESENTATIVES WITH CHAIRMAN OF CONTROL SYMBOL STANDARDIZATION COMMITTEE OF A. I. & S. E. E. HELD DECEMBER 6, 1930

The meeting was held on the above date at Philadelphia, Pa., with the following representatives present:

H. H. Angel, Chairman, Bethlehem Steel Company, Sparrows Point, Md.

W. C. Kennedy, Cutler Hammer Manufacturing Company.

O. L. Holcombe, Clark Controller Company.

J. Rowan, Rowan Controller Company.

J. Magee, Westinghouse Electric and Manufacturing Company.

Mr. Bell, Westinghouse Electric and Manufacturing Company.

Mr. Farley, Electric Controller and Manufacturing Company.

W. J. Fleming, General Electric Company.

A. F. Bowers, General Electric Company.

J. F. Kelly, A. I. & S. E. E.

The discussion was first started on the various symbols used for the standard contactor. Each manufacturer has his own line of symbols which has been used for years. The General Electric Company has had two symbols in use for approximately ten or fifteen years and recently another method of showing their contactors has been tried. As far as can be recalled by the representatives present, most of the companies have adhered to but one symbol. Different methods are used in showing electrical inter-

(Continued on Page 130)

Industrial Power Applications

JOINT MEETING

of the

Association of Iron and Steel Electrical Engineers

and the

MIDDLE EASTERN DISTRICT

of the

American Institute of Electrical Engineers

FRIDAY, MARCH 13, 1931

WILLIAM PENN HOTEL PITTSBURGH, PA.

Program 9:30 A. M.

Presiding, A. C. Cummins, Electrical Engineer, Carnegie Steel Company, Duquesne, Pa.

JOINT MEETING A. I. & S. E. E. AND A. I. E. E.

"Conversion and Distribution of General Purpose D.C. Power in Large Industrial Plants," by R. D. Abbiss, Assistant Chief Engineer, Carnegie Steel Company, Braddock, Pa., and D. C. West, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

"Interconnection Between the Duquesne Light Company and the Davison Coke & Iron Company," by G. E. Dignan, Chief Engineer, Davison Coke & Iron Co., Pittsburgh, Pa., and R. L. **Kirk, Assistant to System Development Manager,** Duquesne Light Company, Pittsburgh, Pa.

"Interconnections of Power Between Public Utilities and Large Industrial Users," by F. O. Schnure, Superintendent of Electrical Department, Bethlehem Steel Company, Sparrows Point, Md.

"Absorption of By-Product Power," by A. Hoefle, Engineer, Toledo Edison Company, Toledo, Ohio, and W. T. Woodmancy, Superintendent of Power, Interlake Iron Corporation, Toledo, Ohio.

PROGRAM 2:00 P. M.

"The Use of Electricity in Large Annealing Furnaces," by J. C. Woodson, Manager of Industrial Heating Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Interconnections of Power between Public Utilties and Large Industrial Users

By F. O. SCHNURE*

Discussion of power connections between industries and utilities will be simplified if we approach the subject by considering the differing conditions under which such arrangements are made. There are three plans in common practice:

1. Where the utility furnishes all the power the industrial uses.
2. Where the utility furnishes the peak power for the industry, with the latter supplying its own base load.
3. Where the utility furnishes the base load for the industry, with the latter supplying its peak power.

Under any of these methods, one also has the possibility of purchase of power by the utility from the industrial. The greatest economies for each party are to be found in potentialities of interchange.

The first condition is a simple power connection with the industry purchasing all of its power from the utility. Under this condition, energy may be purchased in total, as firm (or primary) power, without restriction; or the arrangement may be a combination of firm and secondary power where the industrial contracts for a definite block of primary power, and agrees to regulate or defer its secondary power demand to periods when the utility is best able to supply it.

There are many industrial plants that can operate satisfactorily with a power contract which permits the utility, after due notice, to curtail the amount of power which the plant takes on any day or even during certain hours of any one day. For instance, the peak loads of the utility may occur between 4:00 and 8:00 P. M. while the night load will probably be less than 50% of these peaks. The industrial plant operating on two 8-hour shifts may end its day shift at 4:00 P. M. and start the night shift any time after 8:00 P. M. thus avoiding the peak load period of the utility. Special industrial loads may be carried largely at night with peak load regulation during the day if the night rate is made more attractive than the day rate. When this is done, the industrial plant has prepared the way to obtain power rates considerably lower than when the utility contracts to supply power continuously throughout the 24 hours of every day and 365 days per year. The advantage of balancing demand by promoting night load is recognized by many utilities which allow substantial rate reductions on night load.

Power contracts taking these things into consideration will result in mutual benefit to the utility and the industrial. The utility will be able to generate power cheaper due to steadier load conditions, and the industrial, because power is cheaper, will be able to make greater use of it. Co-operation between the two is essential. While public utility commissions practically guarantee the utilities' return, the industrial's profit and powers of expansion are definitely regulated by the natural laws of competitive business. The more favorable the power rate, the more business both will enjoy.

In discussing the second and third conditions, namely, where the industry supplies some of its own power, I must ask your indulgence in using the steel industry as an example, as I am particularly familiar with such conditions. The general principles will, I believe, apply widely in the relationship between utilities and industry. I refer to the use of power by that part of the steel industry which includes coke ovens and blast furnaces.

Let us consider the second classification where the industrial buys power for its peak loads only. In such instances the industrial has large by-product energy resources to generate cheap power in competition with the comparatively more expensive power from the utility.

In the third condition, however, the utility has available large blocks of cheap power, hydro-electric generated perhaps, so that the industrial's most economic installation is to provide just enough generating equipment to supply power for all vital loads, such as water supply, as well as to supply the peaks of the plant load in order to improve the load factor of the energy taken from the Power Company. In this arrangement the bulk of the industrial's power is supplied by the utility which, for special reasons, may have unusual economic advantages, and the by-product gases of the industrial can be applied to other industrial purposes.

There are certain limits in the purchase of power which the industrial can approach, beyond which operation and equipment are jeopardized. The most important block of power in a steel plant, for example, is that which serves the pumps furnishing cooling water to the Coke Ovens, Blast Furnaces, Open Hearth and Mills, and the power for the cranes and auxiliary equipment in the hot-metal departments. This load must be well protected. Plants operated under either the second or third conditions will carry this as their house bus or vital load, serviced by a turbo generator large enough to handle this load under sub-normal steam conditions. This bus will be connected to the main plant bus by an oil circuit breaker, relayed to open on over-current or under-voltage. When trouble develops on the main bus, this switch will open on over-current, also on an over-loaded system it will open on low voltage; in both instances preventing the house bus load from stalling. In event of trouble on the house bus turbine, the load will be fed from the main bus.

The power situation in a steel plant is generally so concentrated and the loads so heavy that proper protection is a difficult problem. Sectionalizing the bus and load by reactors is the generally accepted method of keeping the short circuit current within due bounds. With this concentration of power, trou-

* Superintendent, Electrical Department, Bethlehem Steel Company, Sparrows Point, Md.

ble at strategic points is likely to affect the vital load, therefore provision should be made to serve it by emergency circuits from the utility's terminus in the steel plant.

Interconnection, besides providing a situation where the utility furnishes power, presumes an interchange of power from the industrial for a remuneration. That this exchange of power has not been more general is due, not so much to the lack of recognition of the potential excess by-product energy available in the steel industry, as to the lack of commercial provision for its utilization. It is true, of course, that there are numerous industrials which do not generate power in their operations.

Economy demands that waste gas and waste heat in steel manufacture should be utilized not only when the resultant power is needed in the plant where the gases exist, but at all times, and interconnection should provide a means of passing such power into commercial use.

Such interconnections do exist and operate because it is impossible to connect two generating systems together without exchange of power at one time or other. A rate structure should be set up that would allow the greatest economic use of these waste gases. The utilities, connected as they are today, supplying power to a greatly diversified group of customers, spread over a large territory, should be able to take this economy power and market it effectively. One way in which the utilities could promote the use of such power is to offer attractive rates.

On this point the late Dr. Steinmetz wrote, "In considering the rate making for such mutual power exchange service it is obvious that the rate paid by the industry to the central station for the power received cannot be the same as the rate paid by the central station for the power returned, but must be materially higher, for two reasons: First, a considerable part of the cost of power is interest, depreciation and maintenance of the distribution system, and this part of the cost is carried by the central station for both forms of power. Second, the central station has no control over the amount of power, and the time of its delivery or reception, thus must be ready to deliver power at any time, whether during peak load or during off peak. This gives the most expensive power, especially as the load-factor usually is very low. Inversely, the central station must receive the power returned whether it needs it during peak load or does not need it, during off-peak. Thus the returned power is the least valuable."

It is well to recognize the kinds of power the industrial has available to return in this interconnection. First, there is that incidental reverse power that occurs when two systems are connected no matter how careful the regulation may be. On a utility service of 20,000 K.W. this exchange power, may vary plus or minus five hundred k.w.h. per hour. Its variation and uncertainty renders it the least valuable, yet it is energy and should have a definite value for a limited quantity. Second, there is the economy power available from by-product gases in excess of the plant requirements. This power should have the same value to the utility as the power generated by its own equipment, considering only fuel, operating labor and repairs, all referred to the load center where it is being used. Third, there is the emergency power the utility may need because of emergencies, in which case the industrial should make every effort to supply the power, for which it should receive an equitable remuneration. There is no difference in principle in the interchange of power between a utility and an industrial, as compared with one utility and another.

This relationship has considerable possibilities in the steel industry, where the blast furnaces, coke ovens and open hearth are all producers of by-product energy (gas, coke braize and steam) available for power generation.

A modern blast furnace produces on the order of 1,000 gross tons of pig iron per day, and for every ton of pig iron approximately 150,000 cu. ft. of gas is produced. This gas will vary from 90 to 100 B.T.U. per cu. ft., the average being 95. A thousand-ton furnace, therefore, will produce 150,000,000 cu. ft. of gas per day or 6,250,000 cu. ft. per hour. Of this, approximately 70% is available for power generation and miscellaneous plant uses. Used in gas engines with a thermal efficiency of 23%, this amount of 100 B.T.U. gas will produce 25,000 k.w.h. per hour. Burned under modern boilers the production will be somewhat less, a thermal efficiency of 18% producing approximately 20,000 k.w.h. per hour.

The coke ovens produce from a gross ton of coal, in addition to other by-products, 11,000 cu. ft. of gas with a thermal value of about 500 B.T.U. used as a fuel in the various heating, melting and annealing furnaces throughout the plant.

In the manufacture, handling and quenching of coke small pieces are broken off which are not suitable for blast furnace use. These fines are screened from the furnace coke and constitute coke braize, which is usually burned under boilers.

With each open hearth furnace of 125-ton capacity, there is installed a 600 HP. "waste heat" boiler from which 75% to 100% of rating is obtained, depending on the operation of the furnace.

A plant producing a large percentage of heavy-section, plain material such as plates, structural shapes, rails, etc., will not consume as much of its own fuel as the plant producing material such as sheets, tin plate, rods, wire, pipe, bars, etc., where the processed steel passes through furnace after furnace. The plain material plant will have more by-product gas per unit of finished product for generating power than the plant producing highly finished products.

In general, interconnections where the industry provides enough power for its base load should provide an incentive for the industrial to make the maximum economical use of its available by-product energy and at the same time make the interchange cost to the utility so attractive that it will represent an economy for the latter to use any surplus power. Under the condition where the industrial purchases most of its power, in districts where coal is expensive and power cheap, the development of the industrial power plants should cover the protection of the vital load only and the use of the by-product gases in manufacturing processes should be developed to the utmost. Every steel plant has an individual by-product energy problem which is constantly changing. The accomplishments of the central stations in fuel

economy in the last decade have a parallel in what has been done and is under way in the steel plants towards the conservation of fuel. The maximum gain to both parties can come from a joint consideration of the potential economies in the interconnection of power systems.

Conversion and Distribution of General Purpose D.C. Power in Large Industrial Plants

By R. D. ABBISS* and D. C. WEST†

It is commonplace to remark that, with the exception of an almost negligible amount, our enormous yearly output of electrical energy is generated in the form of alternating current. It is rather striking, however, to realize that probably one-third of this energy is finally consumed in the form of direct current. Fundamental economy and flexibility in generation, transmission and distribution, together with the rugged simplicity of the induction motor and its suitability for many applications, have resulted in the dominance of the polyphase A.C. system. On the other hand, the flexibility of speed control inherent in the D.C. motor is of such value in many applications that direct current retains a very prominent and apparently permanent place in utilization. In order to realize the advantages of both A.C. generation and D.C. utilization we must pay the price of providing and operating a system of power conversion and low voltage D.C. distribution. Viewed in this light this whole intermediate system takes on the nature of an overhead, or we might even say a necessary evil. Certainly, it is deserving of any attention or study which promises reduction of the overall cost. A considerable amount of time and effort, expended over a long period of years, has brought the apparatus for such a system to a high state of development, and the effort at improvement continues at an increased rate. However, it has probably not been fully appreciated that the economy which this modern equipment makes possible can be fully realized only through careful planning and proper co-ordination and design of the whole system of conversion and D.C. distribution.

In the early days of the electrification of industry, D.C. power was supplied to a large extent by slow speed D.C. generators, driven by reciprocating steam engines. Even today there are still in regular operation an appreciable number of these gigantic affairs, consuming a needlessly large amount of power in the form of losses in both the engine and generator, requiring a considerable force of men for operation and maintenance, and unnecessarily taking up a considerable amount of more or less valuable space. A.C. power is available in practically all present day cases, either purchased or locally generated, and marked economy can usually be effected by changing over to modern, high speed, efficient conversion equipment. Where steam pressure must be maintained for other purposes and where the space is not particularly valuable, the engine driven units are sometimes left in place as standby capacity.

* Assistant Chief Engineer, Edgar Thomson Works, Carnegie Steel Company, Braddock, Pa.

† General Engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

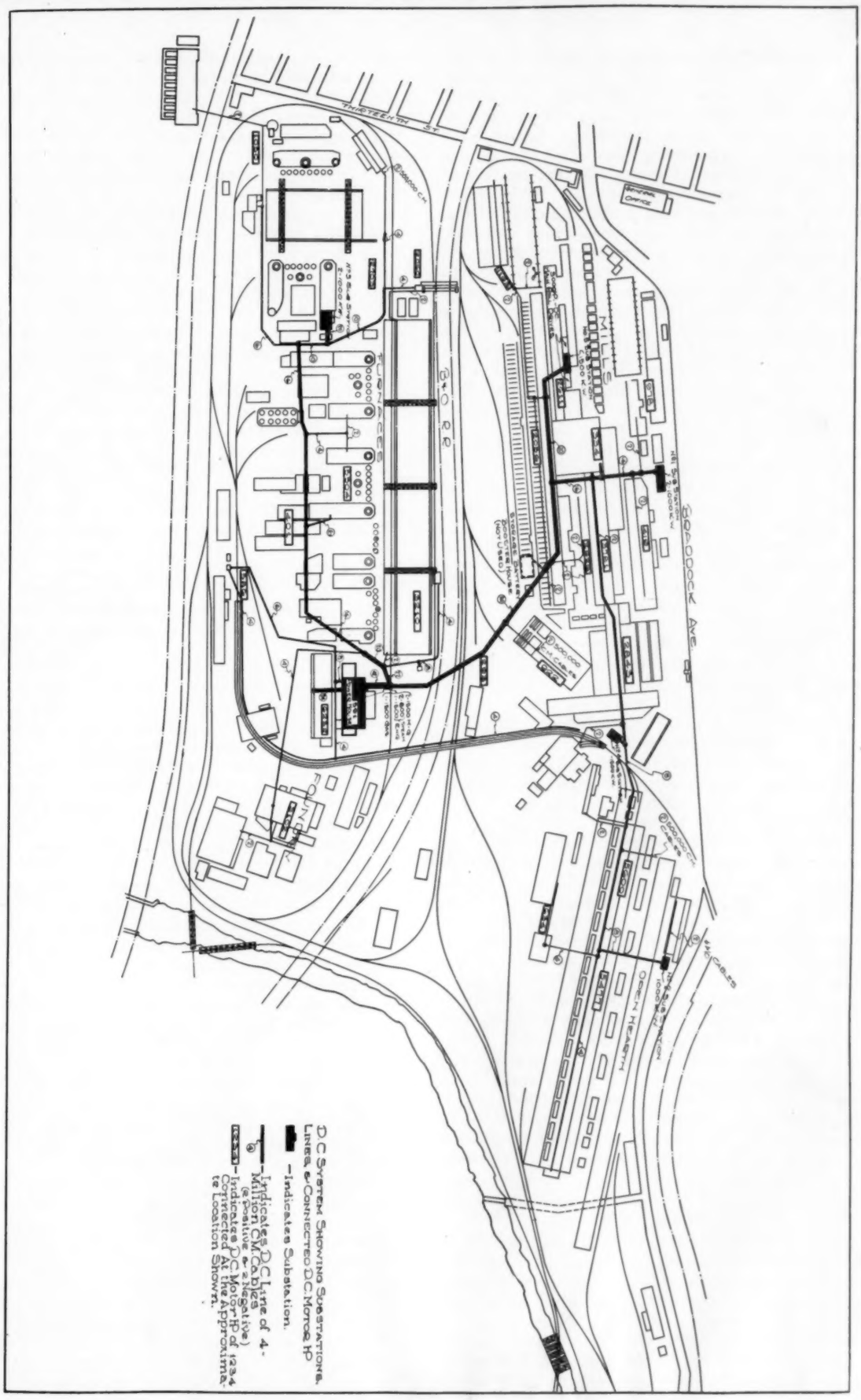
The development of reliable conversion equipment was a definite step forward, in spite of the fact that the early units were relatively large slow speed machines, with correspondingly low efficiency. Even with the later development of higher speed machines, constant attendance was necessary at all times when the machines were in operation, since only manually operated switching equipment was available. Since many large industrial plants have grown up under the limitations imposed by steam driven generating equipment and manually operated conversion units, it is not uncommon to find the total D.C. capacity concentrated in one or two large stations, whereas a large part of the D.C. power must be used at remote parts of the plant. The arrangement undoubtedly represented good economics at the time it was first installed. In many cases, however, a study will show that growth of the plant and the development of new apparatus have gradually effected a change and that the present day result is a more or less costly compromise between high distribution loss, low voltage at the load and an excessive amount of distribution copper.

By eliminating the necessity for constant attendance at each substation, automatic equipment makes it economically feasible to distribute the D.C. substation capacity throughout the system. The average D.C. feeding distance is thus greatly reduced, with a corresponding saving in distribution cost which can be taken either in the form of less copper, reduced losses, or both. If improvement in voltage at the load is necessary, the advantage gained can readily be turned to this purpose. It is, of course, necessary in any case to transmit roughly the same amount of power over about the same distance from the A.C. source to the distributed D.C. load. The fundamental economy lies in the fact that, with distributed conversion equipment, the bulk distribution of this power is over a relatively high voltage, 3-phase circuit, say 6600 volts, instead of a 250-volt, D.C. circuit.

System Study:

The general problem under consideration will arise, ordinarily in connection with the rehabilitation or extension of an existing plant. Where an entirely new installation is to be made, the problem is somewhat simplified in that the practical limitations of an existing arrangement are eliminated. In any case, joint consideration of load, D.C. distribution, substations, and A.C. transmission is essential to a proper analysis and economical solution, since it is only by such a study of the entire system that the major component parts can be correctly co-ordinated and proportioned.

The first step in any such study is a careful survey and analysis of the load requirements. In the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case of an existing plant, complete meter readings are very helpful. Weekly or monthly readings of energy consumption are useful as a general check only if the shape of the daily load curve is known. Graphic ammeter and voltmeter charts, taken both at the stations and at strategic points in the distribution system, will provide a clear picture of existing conditions. The charts should cover at least a full typical day, and preferably at a time when the plant is operating at maximum production capacity in all departments. Usually it will be found necessary to make an allowance in the use of the charts to offset subnormal production, both as regards magnitude and location. If the records are made in summer, and an appreciable portion of the utilization equipment is located out-of-doors or in poorly heated buildings, an allowance must be added to cover winter load conditions. In some cases, this might run as high as 10 or 15%. Some allowance for casual growth is usually made, also.

The object of the load study is to determine not only the magnitude, but also the distribution of load throughout the plant. Ordinarily it will usually be found that sufficient information cannot be obtained from the graphic load charts available, and that it is necessary to resort to a consideration of installed motor horsepower. Inspection of a large map of the plant, such as shown on Fig. 1, will at once suggest natural sections or areas into which the system can be subdivided so that the installed horsepower can be lumped in suitable blocks. For example, it is convenient to determine and mark on the map the total motor horsepower installed in each mill, large building, or group of small buildings which would naturally be fed as a unit from the D.C. system. In studying an exceptionally long and narrow plant, it was divided up into transverse strips, each 100 ft. wide, and the installed horsepower was determined for each strip. Having arrived at the amount of motor capacity in each section, a factor must be applied to obtain the equivalent average load at the station bus with the plant operating at full production capacity. This factor will depend on the diversity of utilization and on the distribution efficiency, and is difficult to evaluate very closely. Although the available data are limited, experience seems to indicate that for large steel plants the load at the substation bus will average about 25% of the installed motor capacity, both expressed in either horsepower or kilowatts. In one case, graphic load charts indicated a factor of 26% for summer conditions. It is always very desirable to establish this factor for the particular type of plant under consideration by actual average load measurements at the existing stations. A single motor which is large in comparison with the size of the individual conversion unit, such as a main roll drive in a steel mill, should be given special consideration. Most such motors are now supplied by separate motor generator sets to obtain variable voltage speed control.

In selecting the most economical arrangement to meet the overall requirements, several fundamental relations should be borne in mind. The investment in substations will be greater as the number of substations and conversion units is increased, for a given system capacity. On the other hand, assuming a given average voltage at the load, either the distribution losses or the investment in distribution copper, or both, will be considerably reduced by smaller stations more closely spaced. Again, the cost of copper necessary to maintain the desired voltage with one or more units out of service will decrease as the total capacity is divided into a larger number of smaller conversion units. The problem is to strike a suitable balance between these increasing and decreasing factors. Any plans or probabilities of expansion or other changes in the plant layout must be given careful consideration since they may have a determining influence.

In most cases, local conditions will dictate a limited number of available substation sites. Inspection and preliminary study of the load map will then indicate several possible substation arrangements, as regards size and location. Rough calculations and practical operating considerations usually suffice to select one or two of these arrangements as being obviously best suited as a working basis for detailed study and final design.

In a large plant with distributed conversion capacity the main D.C. distribution system naturally takes the form of a heavy network connecting all substation buses together into what might well be designated as the plant bus. The various conversion units feed into this plant bus, and the load feeders are tapped off from it in much the same manner as though the whole conversion equipment and bus were concentrated in a single substation. With this arrangement, the main distribution copper is utilized not only for feeding the load under normal conditions, but also as tie capacity between stations which permits shutting down part of the substations during periods of light system load conditions with one or more units out of service. As a criterion of reliability of the D.C. power supply it is considered necessary, in most large plants, to provide a system capable of maintaining normal production with one conversion unit out of service. In general, simultaneous outage of two units is considered as a rather extreme emergency during which some slowing up is to be expected in the adjacent sections, but which should not require shut down of any part of the plant due to low D.C. voltage.

Before proceeding with the calculation of the amount of distribution copper required with each of the schemes selected, it is necessary to decide on the approximate distribution efficiency and load voltage conditions which are necessary or desirable in order to best satisfy the overall purpose. For example, suppose it be decided to design for 6 per cent total distribution loss, as a first approximation. Then a uniform average drop of 3%, or 7.5 volts, be allowed at all points between the plant bus and the load, the average of the voltage drops at all points along the length of the plant bus must also be 3%. With the fairly uniform loading which usually obtains, the maximum voltage drop on the plant bus would occur about midway between stations and would be about 5%, or 12.5 volts. Assuming 250 volts at the substation buses under normal load, the minimum voltage at the load in any part of the plant would be 230 volts, which is ample. With a given plant and scheme of substation location, these conditions, or requirements, completely define the amount of distribution copper necessary under normal conditions. So far, the only requirement as to size and number of conversion units is that each sub-

station have enough total capacity to supply the load which it naturally picks up from the system in its particular location.

The next step is to check back against the abnormal condition of one conversion unit being out of service. Again limits must be established, but only as regards voltage since distribution efficiency is not important in this case. Suppose it be decided that 215 volts is the minimum permissible load voltage at any point in the system under this condition. Assuming 7.5 volts uniform drop between the plant bus and the load, as before, this permits a minimum plant bus voltage of 222.5 volts, which is 15 volts below the corresponding value previously decided upon for normal conditions. This difference in voltage drop is available for feeding the normal load current over a greater than normal average distance in the general region of the machine out of service. The amount of plant bus copper necessary to meet these or similar requirements of abnormal operation will depend on the size of conversion units and on the amount and location of spare capacity. If a complete spare conversion unit were installed in each substation, the problem would be solved, since the average feeding distance would be the same as under normal conditions, even with a unit out of service in each substation. However, the resultant investment in conversion equipment would be somewhat more than necessary, which would offset, to a considerable extent, the savings to be effected by distributed conversion equipment.

Automatic voltage and load regulating equipment makes it feasible to divide up the spare capacity and distribute it among the various substations. In most applications, it is difficult to match the actual normal load with standard commercial ratings even by resorting to the undesirable expedient of installing a miscellaneous assortment of machine sizes on one property. For example, a 1600 KW. substation load would require 2000 KW. capacity. Probably, two 1000 KW. machines would be selected, in preference to one 2000 KW., in order to provide operating flexibility and to minimize the effect of machine outage. The automatic regulating equipment makes full use of the extra capacity in each machine as spare capacity in case of machine outage at this or other substations on the system. Assuming one of the two units in this station out of service, the other would be badly overloaded and would soon have to be shut down were it not for the automatic regulator which functions to maintain the load within the capacity of the machine by reducing the voltage as much as necessary to shift the extra load to other substations. In case of machine outage in an adjacent station, the regulators permit both machines in this station to assume load up to a predetermined limit at normal voltage, beyond which the voltage is automatically reduced to shift the surplus load on to the next station.

From the above it will be apparent as the study progresses it may be necessary to increase either the size of copper or the capacity of conversion units at certain locations, in order to come within the prescribed limit of permissible plant bus voltage reduction under abnormal conditions. In considering the spare capacity available, it is customary to assume that the load limit regulator will be set at about 110 per cent of machine rating, thus adding, in effect, 10 per cent capacity in each machine. This is considered good operating practice since this setting has to do only with operation under the temporary conditions with one or more machines out of service. Under normal conditions, the machine capacity must, of course, be sufficient to prevent overloading. Since the standard machines for this service are nominal rated to carry 125 per cent load for two hours the windings will not exceed a safe temperature rise at 110 per cent load. Increased maintenance expense on current collecting parts is to be expected, of course, as a result of any prolonged overload operation but the occurrence is so infrequent that this is not considered serious.

Parallel Operation:

In considering multiple station systems, or multiple unit stations, it is necessary to bear in mind the fundamentals of parallel operation. With all conditions fixed and constant, satisfactory division of load between units could be obtained by simply adjusting the voltage of each unit to a proper value for the given conditions. However, slight variations in certain conditions, such as load or temperature, will cause or initiate large variations in load division unless the whole system is so designed and adjusted that each conversion unit tends always to shed, rather than assume load. In any practical case, therefore, stable parallel operation can be effected only if each conversion unit operates with a drooping voltage characteristic, or equivalent, with respect to all other conversion units.

The division of load between substations is determined by the relative substation bus voltages, and the relative resistances between the substations and the points where the loads are tapped off. The desired load division should be obtained as far as practicable, by proper location of stations and proportioning of main distribution copper, but in some cases it is necessary to adjust the full load bus voltages to somewhat different values in order to make each station take its proper share of load from the system. At the same time, it is necessary to adjust all stations to substantially the same no-load voltage in order to prevent the lower voltage units being shut down on reverse current during periods of light load. This can best be accomplished by providing each station with an adjustable drooping voltage characteristic. The no-load voltage of all stations can then be set at the same value, say 5 per cent above the desired average full-load voltage of the system, and the amount of voltage droop at each station varied to give the desired load division. The small droop in the bus voltage characteristics, together with the voltage drop in the main distribution copper between stations, provides an inherently stable system under all load conditions.

A slightly drooping bus voltage characteristic is also the simplest and most effective method of insuring proper parallel operation of two or more units in the same station. Stable parallel operation of flat compounded or over-compounded machines is possible only when they are provided with a low resistance equalizer connection, and even then considerable manipulation of the field rheostats is required to maintain proper load division under all conditions of temperature and load. On the other hand, with shunt machines, parallel operation is in-

herently stable, load fluctuation does not materially affect load division between machines, and the effect of temperature variation is minimized. For unattended automatic operation, special regulating equipment is required for satisfactory parallel operation on a flat or rising bus voltage characteristic.

Where voltage regulators are used, the sustained bus voltage is determined by the regulator characteristic, although the instantaneous load division on very fast load swings is largely dependent on the inherent machine characteristics. To effect the desired drooping bus voltage, the standard voltage regulating element is provided with a current bias coil, which gradually recalibrates the device for slightly lower voltage as the load increases. The amount of droop can be readily adjusted by means of a small rheostat in series with the current bias coil, thus providing a convenient method of obtaining proper load division between units and between stations. It should be noted that a drooping bus characteristic does not mean that the bus voltage drops below normal value at full load, but that it drops to normal value at full load from a slightly higher voltage at no load. Experience has shown that about 4 to 6 per cent droop is entirely adequate as regards parallel operation, and further, that from a utilization viewpoint, the effect of this small increase in no load voltage is negligible in practically all industrial systems.

Sectionalizing of the D.C. System:

There are two general methods of handling faults in D.C. distribution systems. The first is typified by the usual practice in D.C. Edison systems where the distribution system comprises a heavy network of underground lead-covered cables solidly tied together at frequent intervals to form a huge grid, from which the individual loads are fed through the usual service fuses. Each feeder cable between the grid and the substation bus is protected at each end by a fuse or a circuit breaker, which is designed to trip only in case of a fault in that cable. There are a large number of these cables, and the isolation of one does not seriously affect the grid voltage. It is the intention that faults in the grid will be burned off and, in the case of underground lead covered cables, this will ordinarily occur quickly, without extensive damage or communication to other circuits, and with only a momentary dip in the grid voltage.

The second general method is typified by the standard practice in D.C. railway systems, where the distribution system is completely sectionalized with the intention of immediately isolating any fault in the D.C. system. In this case, one side of the system is always solidly grounded, and the construction is necessarily such that faults between the contact system and ground are of relatively frequent occurrence. Furthermore, the higher voltage machines used in railway service are more susceptible to flashover on severe short-circuit. An attempt to burn off short-circuits is likely to result in annealing trolley wire, or in other extensive damage, with considerable resultant expense and interruption to service. The whole system is divided up into sections, each of which is fed separately from one or more substations through feeder circuit breakers. In many cases, the system is further sectionalized by installing tie buses, with sectionalizing breakers, between substations. In case of fault, all breakers directly connected to that section must trip. Overload tripping devices have proved to be inadequate for this purpose, because, in the ordinary railway system, the current incident to a remote fault is of less magnitude than the legitimate load swings normally imposed on the same feeder. With the advent of the unattended automatic substation, short-circuit detector automatic reclosing feeder equipment was developed, which provides positive discrimination between faults and legitimate load swings and, having tripped, remains open until the fault has been cleared.

The D.C. system of a large industrial plant is more or less of a cross between the two types discussed above, and there seems to be no well established practice as regards sectionalizing. The system is normally ungrounded and the distribution system is composed of insulated cables, with the result that faults in the distribution system are of infrequent occurrence as compared with a railway system. However, a considerable number of cables are ordinarily racked together in overhead runs extending through the various plant buildings, often under adverse conditions of dirt, heat and fumes. An attempt to burn off a fault on one of these cables presents the possibility of starting a fire, or of communicating to other circuits with extensive damage and interruption of service. Some large industrial plants are operating with the entire D.C. distribution system solidly tied together. Others separate the more troublesome circuits and connect them through feeder circuit breakers to the nearest substation bus. Still others consider it well worth while to completely sectionalize the system. The decision will rest largely on local considerations.

It has previously been stated that the main distribution system naturally assumes the form of a plant bus, connecting between all substations. This can readily be separated into several parallel circuits, each connected through feeder breakers to the substation buses. By proper attention to the distribution of load on these several circuits, the copper can be used effectively. Further sectionalizing can be accomplished by installing breakers at the points where the main blocks of load are tapped off the plant bus, and by feeding nearby loads direct from the substation bus through feeder breakers. For any case, short-circuit detector automatic reclosing feeder equipment is available which will adequately serve its function of remaining closed on legitimate load swings, tripping out on faults, and reclosing only when the fault has been cleared. If faults on the main distribution system are to be burned off, the conversion units should be capable of stable operation down to very low voltage. Otherwise, a severe fault will probably result in a complete system outage, with considerable difficulty in restoring service.

D.C. POWER DISTRIBUTION SYSTEM AT EDGAR THOMSON WORKS—CARNEGIE STEEL COMPANY

The arrangement of the direct current system at these works is a typical example of a large industrial D.C. network which is the result of additions to the system from time to time to supply the increases in demand due to growth and changes in

the plant. This arrangement probably differs to some extent from the arrangement that would be proposed after a study of the requirements of a similar but altogether new installation.

The original installation consisted of two 400 KW. Buckeye horizontal tandem compound engine generators and one 800 KW.—vertical cross compound engine driven generator. One of the 400 KW. units was grounded and used to supply power to the larry cars in the Furnace Department, the other units being used to supply the current required by the other departments. Power was supplied to each consuming department over separate feeders from the Power House, each feeder having a switchboard panel equipped with a single pole circuit breaker and double pole knife switch. There were a total of sixteen 1,000,000 C.M. cables leaving the Power House, four of which supplied the Furnace Department and two each supplying the following: Metal Mixer, Foundries, Converting Mill, Bloom Mill, Rail Mills and Finishing Mills.

Care was exercised at this time to avoid the interconnection of any feeders.

Several years later the power supply was augmented by the addition of a second 800 KW. generator which was a duplicate of the one previously installed and the feeder lines to the Finishing and Rail Mills increased to take care of the additional load.

The installation of an electrically driven Rail Mill, which consisted of two main roll trains each driven by a 1500 H.P., 250-volt, D.C. motor together with auxiliary motor load totaling about 1200 HP. increased the power demand on the Power House nearly 100%.

To provide this additional power, two 1500 KW., 250-volt, D.C., vertical cross compound engine driven generators were installed, together with 10 pair of 1,000,000 C.M. cables, extending from the Power House to the New Mill.

After the mill had been put in operation, it was found that the load on the generators, which averaged about 80% of rating with an occasional peak of 110%, would drop considerably when the mill was shut down. This caused the engines to race upon the sudden reduction of load, and they did not pick up speed quickly when the load was applied, and since these periods of low power consumption were very frequent due to the operation of the mill, the load fluctuated to such an extent that the operating conditions were not at all satisfactory. The installation of a 1500 KW. blast furnace gas engine driven generator at this time did not improve the load conditions in the Power House as its operation was very irregular at times due to the fluctuations in the gas quality.

A storage battery with the necessary M.G. sets with floating regulators having a capacity of 5000 amps. for one hour or 15000 amps, momentarily was installed midway between the Power House and the mill to correct this fluctuating load condition. The installation of this battery permitted the engines to carry the average load of the plant absorbing the charge when the mills were shut down and discharging during starting and other periods of high power consumption. On account of the physical location of this battery, each mill feeder was connected to the main feeders at the battery building instead of running directly to the Power House as in the previous arrangement.

Since the increased load at the Blast Furnace Department was taxing the capacity of the cables previously installed, it was found necessary to add

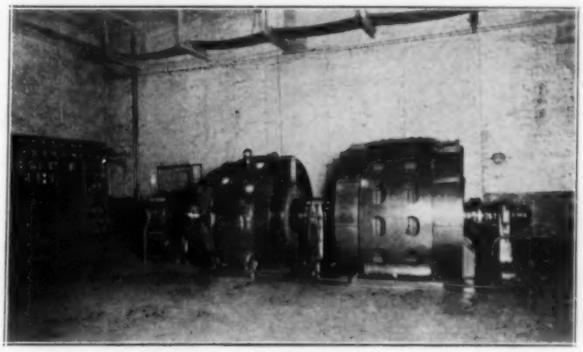


FIG. 2

new cables over the same route. In installing these feeder cables, they were all connected in parallel forming a common bus for this department, the individual loads being connected to main bus either

FIG. 3

through breakers or knife switches as the nature of the load required, thus taking the first step in forming the D.C. network in our plant. This arrangement, on account of the intermittent nature of the load required, made it possible to supply current to this department without an excessive voltage drop

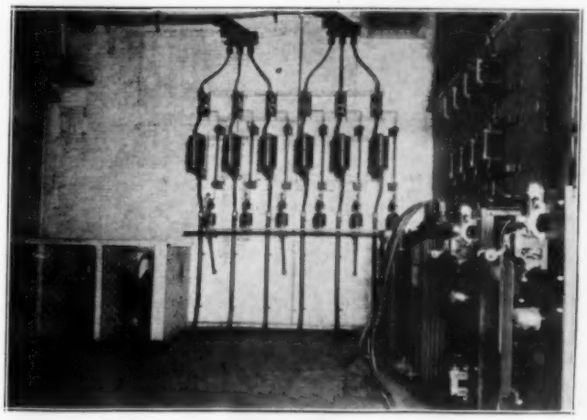


FIG. 4

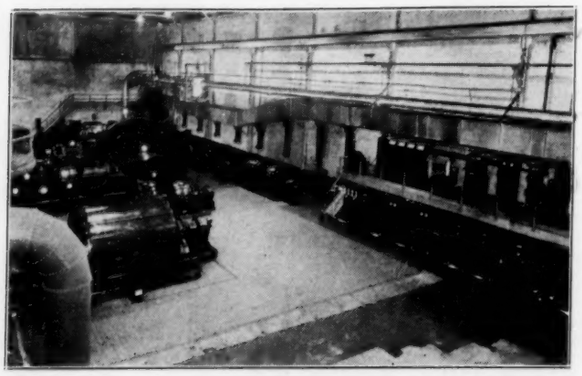


FIG. 5

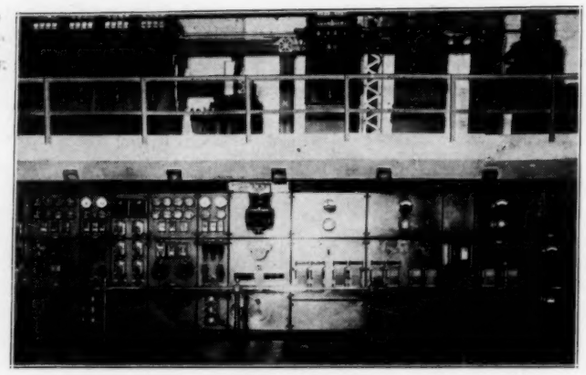


FIG. 7

and with the least amount of copper. It was later found necessary to install two 1000 KW. motor generator sets located in #3 substation about 1500 ft. from Power House to supply the requirements of this department.

In order to meet the increased power demand in the Mill Department caused by the installation of a new Open Hearth Plant together with a new Bloom Mill and a new Rail Mill, a 3500 KW., 25-cycle, 6600-volt, A.C., turbo generator was installed in the Power House with 6600 volt feeders to three new 1000 KW. Motor Generator Sets, two of which were located in #1 Substation near the new mills and one in #2 substation located near the Open Hearth Plant. Due to certain operating conditions, which were deemed advisable to maintain, the two Substations were connected through eight 1,000,000 C.M. cables. The feeder cables in the mill department were all connected together and individual loads fed through breakers or knife switches exactly as had previously been done in the Furnace Department, except that certain loads, such as the Pouring Cranes in the Open Hearth Department, were connected direct to these cables as it was deemed more desirable to protect the operator rather than the equipment. Thus the first step in the Mill Department in the general scheme toward the present D.C. system was taken.

Since the eight cables connecting the two substations ran through the Mill and Open Hearth Departments, it was found convenient to tap the mill feeders directly to this bus. Later when the storage battery was removed, the feeders for the Converting, Blooming and Finishing Mills were connected to the electrically driven rail mill feeder, and this feeder in turn connected to the bus between #1 and 2 Substations, thus completing the network or main bus system in the Mill Department.

In order to improve the parallel operation of the Substations with the engine driven generators, the control equipment was changed from manual to full automatic at which time the series fields, which had been added under the manual control arrangement,

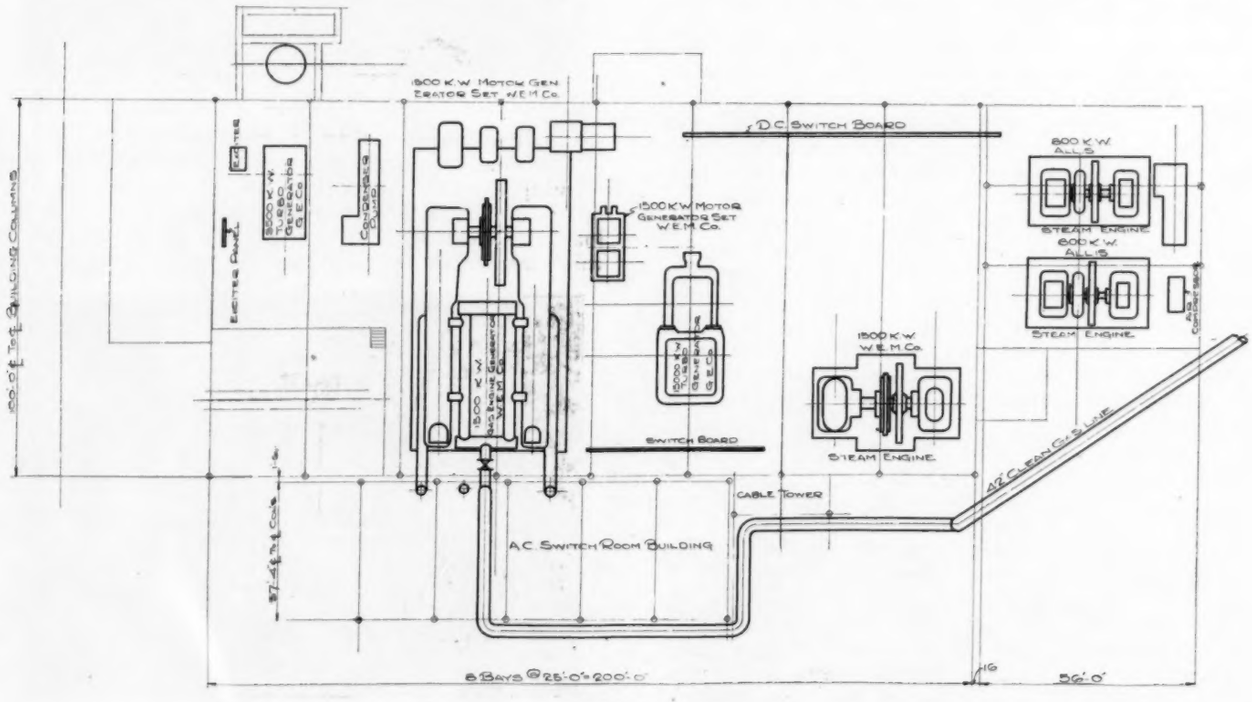


FIG. 6

were removed; giving the machines a drooping voltage characteristic which was necessary under automatic operation.

Since power failure of the network had occurred from time to time due to crane booms coming into contact with the 6600-volt line or due to short-circuits which developed on the D.C. system itself and also as the load had become rather far removed from the source of power causing the operation of the generators at voltages somewhat higher than were deemed economical, it was decided to install three additional 1500 KW. MG-sets near the load centers. Accordingly one new set was installed in the Power House, one in #4 Substation near the

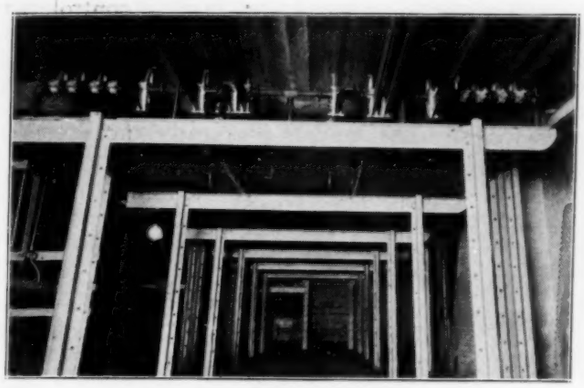


FIG. 8

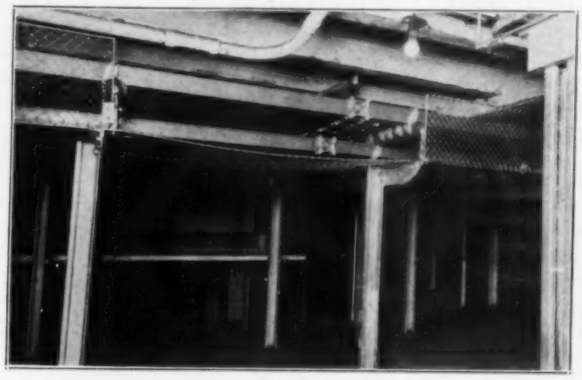
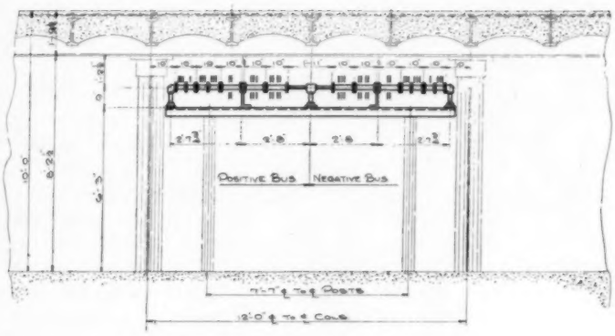
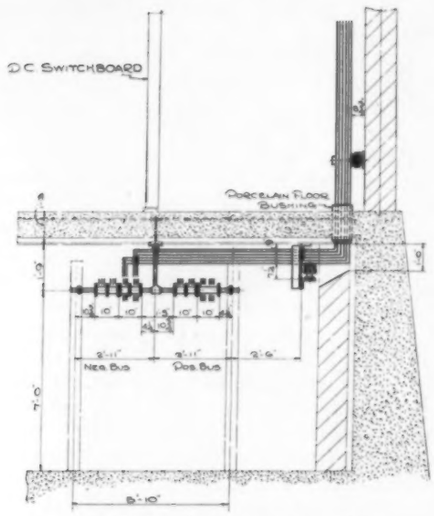


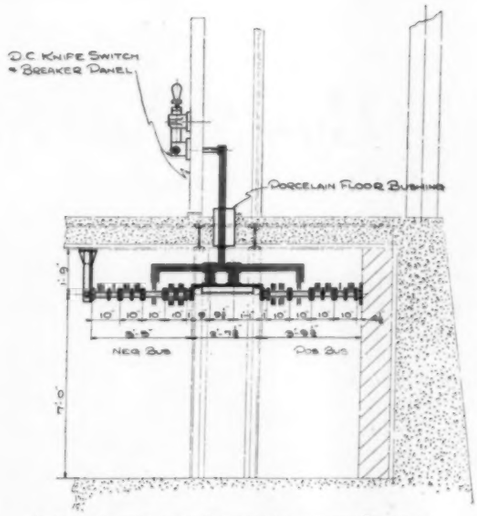
FIG. 9



Section Thru Main D.C. Bus System Located Under Power House Floor



Section Showing Connection Between Bus Located Under Power House Floor and Outgoing Feeder.



Section Showing Typical Feeder Connection Between D.C. Breaker Panel and Bus Located Under Power House Floor

FIG. 10

Converting Mill, and one in #5 Substation near the electrically driven rail mill. These two substations are provided with filtered air. The result of all these changes is shown graphically in Fig. 1. Interior views of Substation #5 are shown in Figs. 2, 3, and 4.

By means of the installation of the last mentioned equipment, we have been able to reduce the unaccounted for power losses about one-half, which is indicated by the fact that the generators are now operating at from 250 to 260 volts instead of 270 to 280 volts as was required previously, maintaining better voltages at the points of power usage.

The reliability of the Electric System as a whole was furthermore increased at this time by the replacement of the overload devices on the A.C. Line, which were of such character that they could not be depended upon to disconnect that portion of the line on which trouble had developed and would overload the turbo generator, causing it to shut down and consequently throw the load on the company's 44,000-volt interworks connecting line. If the overload devices on this line failed to operate, it would overload the generators at one of the other plants furnishing this power, causing further trouble on the system.

The application of satisfactory overload devices on the A.C. line and the replacement of the overload devices on the 3500 KW generator with current limiting reactors, together with the installation of a 15000 KW. turbo generator which is self protecting on short-circuit and will not shut down on overload, makes it possible for any A.C. feeder to disconnect itself from the Power House in case of trouble without shutting down the generators feeding the HZ line or any substation other than the one to which it is directly connected, as it is the practice to operate each substation on a separate line. Furthermore, since all the D.C. generators of the original M.G.-sets were self-excited machines obtaining the power for operation of the substation switching equipment from the net work, a voltage drop accompanying any sizable disturbance on the system would cause the generator to become unstable and the set would be shut down. If this voltage remained low, the switching equipment would not function properly, making it impossible to re-start the machines. To remedy this condition, a 250 volt battery was installed in the Power House and was connected so as to operate the starting features of the two sets in the Power House and those in the new substations. The new MG-sets were each equipped with separate exciters and had automatic current and voltage regulators incorporated in their control, making them capable of stable operation under any condition of bus voltage or load. The operation of this equipment, which in turn has kept the voltage available to the old substations above the critical point, has eliminated any trouble previously encountered in starting the MG-sets.

Fig. 5 shows an interior view of Power House including two of the before mentioned MG-sets.

Fig. 6 shows the General Plan of equipment in the Power House.

Fig. 7 shows an enlarged view of the switchboard panels and breaker equipment for the D.C. generators.

The power wiring to the D.C. generators in the Power House and to the outgoing feeders were originally weatherproof insulated cables carried on porcelain insulators. As the extent and capacity of the D.C. system increased, these cables took up a great deal of space in the cellar of the Power House, making it difficult to inspect or repair them, and the insulation on the cables added considerably to fire hazard. It was therefore necessary to replace this wiring by bare copper bar construction when the new machines were installed. This is shown on Figs. 8 and 9 and also on Fig. 10.

The D.C. generating capacity concentrated on the power house bus made possible stresses up to 10,000 lbs. per 6 ft. length of conductor under short-circuited conditions and the space available was very much restricted on account of engine foundations, pipes, columns, etc. The bus bar arrangement shown made it possible to get a total of seven separate 2-wire circuits, totaling 25,000 amps. through a space 11 ft. x 2 ft. nearest the ceiling. All the positive bars are segregated from the negative bars with a minimum spacing of 30" and there is head room under the safety screen for a person of average height.

Absorption of By-Product Power

By A. HOEFLE* and W. T. WOODMANCY†

GENERAL

Complete and economic utilization of by-products is an end much to be desired in modern industry. Studies that have been made with reference to such an end have frequently revealed promising opportunities for co-operation between manufacturing plants and electric utilities. Some combined arrangement will often prove out to be an economic benefit to both parties. These opportunities may arise in situations of which the following are two outstanding examples:

* Engineer, The Toledo Edison Co., Toledo, Ohio.
† Superintendent of Power, Interlake Iron Corporation, Toledo, Ohio.

(1) A manufacturing plant uses large amounts of process steam. Whether live steam is used or the exhaust from a private generating plant, the overall economies leave much to be desired. In the first case, none of the power possibilities of the live steam are utilized. In the case of exhaust steam, it would be a rare plant indeed whose steam and power needs were balanced as to quantity and time of occurrence. The result again is not always satisfactory operation.

(2) A manufacturing plant produces quantities of energy containing by-products far in excess of its own power requirements. No incentive exists for efficient operation of the generating plant and many wastes will occur.

In both of the above examples as well as in others that could be mentioned, there are advantageous opportunities for co-ordinating the efforts of industry and utilities. Whatever form this takes, it must be based on a thorough understanding and appreciation of each others problems.

The basic idea in the co-ordination schemes lies in the construction of efficient stations that will operate at a good load factor by feeding into the utilities' systems whenever the manufacturers' demands for steam or by-product power drops off. Several methods of accomplishing the actual co-ordination may be mentioned:

(1) Use of excess energy containing by-products in the utility's plant. This plan depends on the reasonable proximity of the source of the by-products and the central station's plant.

(2) Sale of exhaust process steam to a manufacturing establishment and supplied by a central station's generating plant. This also requires that the plants be reasonably close together.

(3) Transfer of excess power of a manufacturer's generating plant to the utility system. This resembles the usual interconnection of power plants.

(4) A joint plant arrangement in which manufacturer and utility own and operate a generating station and share the fixed and variable costs in proportion to benefits derived.

These and other plans will suggest themselves whenever an analysis is made of possibilities of industrial waste elimination. The Deepwater Plant in New Jersey is an excellent example in which two utilities (American Gas & Electric Co. and the United Gas Improvement Co.) have a joint plant agreement between themselves and with an industrial organization (E. I. du Pont de Nemours & Co.) The remainder of this paper will describe another example of a somewhat different arrangement but attaining similar overall economic benefits.

A TOLEDO EXAMPLE

The Toledo plant of the Interlake Iron Corporation consists of two blast furnaces, coke ovens and the usual auxiliaries. Pig iron for domestic sale is the primary product as the plant does not include either an open hearth furnace or rolling mill. The by-products of this plant are large and numerous and its power requirements are relatively small. Tar, coke, coke oven gas, and blast furnace gas are the by-products capable of being used for power generation. It has been proven economically unsound to use any of these by-products as fuel in competition with present day cheap coal for power generation if any other market is reasonably available for them. Ordinarily there is a market available for all these by-products except blast furnace gas and coke breeze. These latter fuels are used in most steel plants for power generation but even then there is an excess that cannot be used and is therefore wasted. That was the situation at the Toledo furnace plant a few years ago. The blast furnace gas and coke breeze were burned very inefficiently to produce plant power and a very great deal was wasted.

With the end in view of securing more complete utilization of by-products, arrangements were made in 1924 with The Toledo Edison Co. for disposing of excess power. A modern generating station was built by the furnace company, the steam production portion of which was arranged for maintaining steam output using either blast furnace gas or coke breeze. This latter feature was required if any degree of control of load output was desirable. Storage of the blast furnace gas was considered impracticable as long as the more easily stored and otherwise valueless coke breeze could be fired. The plant today consumes all of the blast furnace gas as produced and utilizes the coke breeze to take up the fluctuations in gas supply.

On the part of The Toledo Edison Company, the interconnection seemed desirable because it would have several beneficial results among which are the following:

(1) An economical source of power due to the utilization of otherwise waste products.

(2) Diversity of supply making it possible to reduce spare generating capacity on the Toledo Edison Company system. This benefit became a reality when the furnace plant's output went to a firm power output.

(3) Sets up a good all around economic condition. In this case, the sale of excess by-product power reflects in the improved ability of the iron company to maintain operation in the face of adverse business conditions. This results in an overall improvement to the community which cannot fail to react favorably to everyone, including the utility.

PHYSICAL DESCRIPTION

The Toledo Edison Company serves the city of Toledo, Ohio, and an extensive area in the northwestern portion of the state. The backbone of the transmission network is a steel tower belt line entirely encircling the city. The principal generating source is steam driven Acme Station with a capacity of 126,000 kva. and located inside the belt line

FIG. 1

(See Fig. 1). Substations and interconnections with other companies are made to the belt line as required. Primary transmission is at 69,000 volts, three

phase, sixty cycle. The greater part of the system load is within a few miles of Toledo, so it may be seen that no long distance transmission problems are involved.

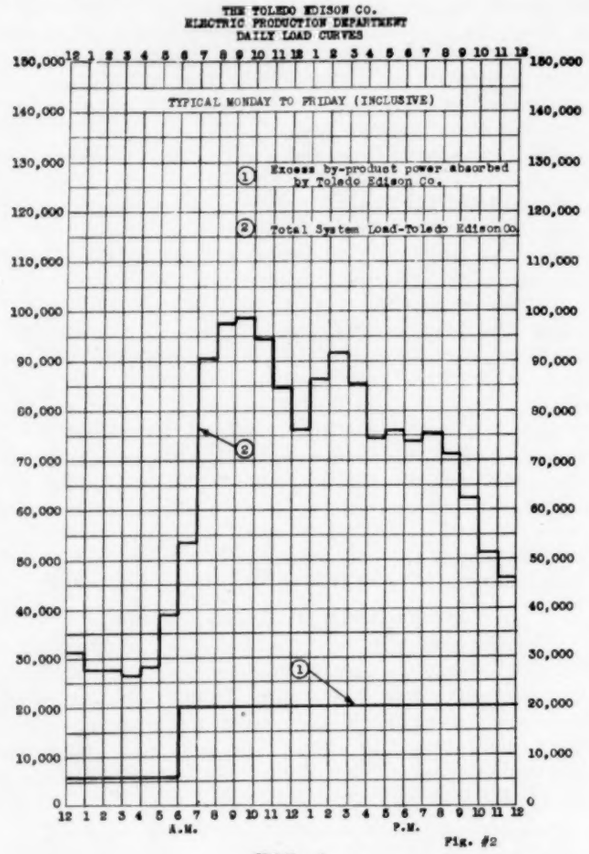


FIG. 2

The blast furnace plant of the Interlake Iron Corporation is located on the Maumee River about one mile from Acme Station and is also inside the 69,000 volt belt line. The two blast furnaces have a combined daily capacity of 1500 tons of iron and incidentally produce eight million cubic feet of blast furnace gas per hour. The principal combustible constituent of this gas is carbon monoxide, (about 25% by volume) and its heat value is in the neighborhood of 85 B.T.U. per cubic foot. Two things discourage the storage of the gas in holders or its transportation over any considerable distance; these are:

(a) The enormous volumes of the gas that have to be handled in relation to its heat content.
(b) The fact that very little air is required to produce a highly explosive mixture.

The result is that the gas must be used in close proximity to the point of production. At the Toledo plant, 30% of the blast furnace gas is consumed in the preheating air stoves that serve the blast furnaces. The remaining 70% is available for power generation.

The coke ovens produce the coke required in the blast furnaces, about 1350 tons per day, and eleven million cubic feet of coke oven gas which is sold to a gas distributing company. In the ordinary handling of coke about the plant, there is produced a quantity of fine coke particles that has little use or sales value unless it can be burned. About 4% of the total coke produced results in this material, which is known as coke breeze.

The steam generating equipment consists of five boilers totaling 9800 HP. Three of these are 2200 HP. each and are equipped with pressure type burners for burning blast furnace gas. In these burners the air is under pressure and carefully controlled. This is necessary in order to secure the best burning mixture for the low B.T.U. gas. The other two boilers are 1600 HP. each and equipped with chain grates for firing the coke breeze. Steam pressure is 250# gauge with 125° superheat.

Generating equipment consists of two 12,500 kva. turbo generators, the output of which is stepped up to transmission voltage of 69,000 volts at an outdoor substation located on the furnace plant's premises. Two banks of transformers are used having a capacity of 10,000 kva. each. Metering is at transmission voltage. An aerial line about one-half mile in length completes the interconnection with The Toledo Edison belt line.

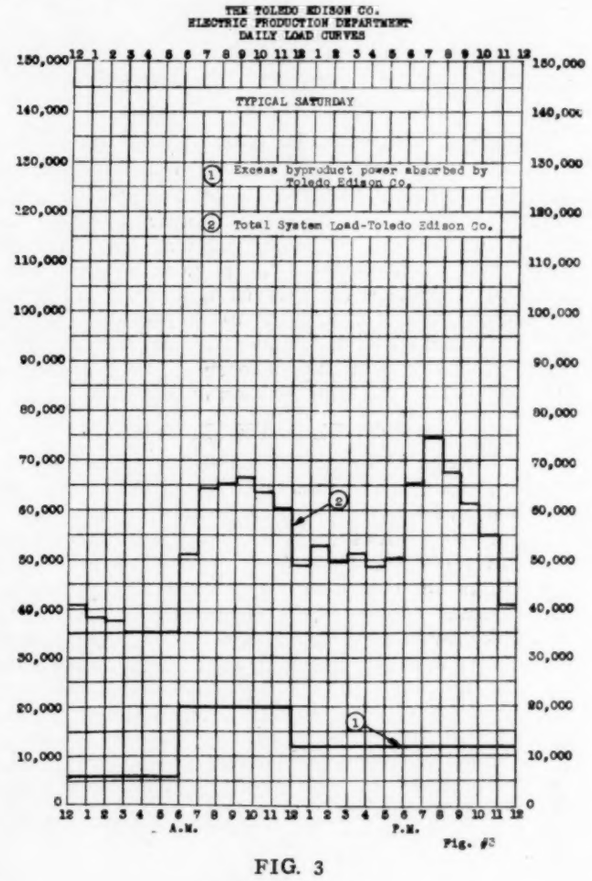


FIG. 3

OPERATION

For the first year and a half of the connection, the furnace plant's output was on a dump power basis. The inherent lack of reliability that a dump power arrangement incurred was not entirely satisfactory to either party. The furnace plant secured only partial utilization of its by-products and the utility failed to realize on operation economies that diversity of firm power supply makes possible. At

the end of this period an extension of the generating equipment at the furnace plant made it possible to enter into a firm power agreement that has worked successfully. The block of power to be taken was set at a fixed amount for each hour of the week and is mutually suitable to the operating conditions of the two companies. Reference to Figures 2, 3 and 4 shows the relation of the excess by-product power absorbed by The Toledo Edison Company to the total load of its system.

The furnace plant's generating station is operated so that the average power factor of the energy supplied to The Toledo Edison Company will be equal to the average power factor of the Edison Company's system. The average power factor of the Edison Company's system is taken to be 85%. A power factor correction factor is employed in billing the cost of power absorbed so that variations from the average will be taken into account.

The agreement between the two companies also provides that the Edison Company will supply the furnace plant with power in the event the latter's plant is unable to do so. This has proven a benefit on several occasions. An interesting result of the interconnection has been to steady the furnace plant's bus voltage. Before the parallel was made, the bus voltage at the furnace plant was inclined to fluctuate considerably due to the heavy starting currents of plant apparatus. The interconnection with the large utility's transmission network has practically eliminated this annoyance.

After over five years experience with this interconnection, the two parties concerned are able to report very satisfactory operation. No unusual problems have arisen that are due to the interconnection. Complete co-operation exists between the operators of the two systems in the routine day to day maintenance and switching requirements that arise.

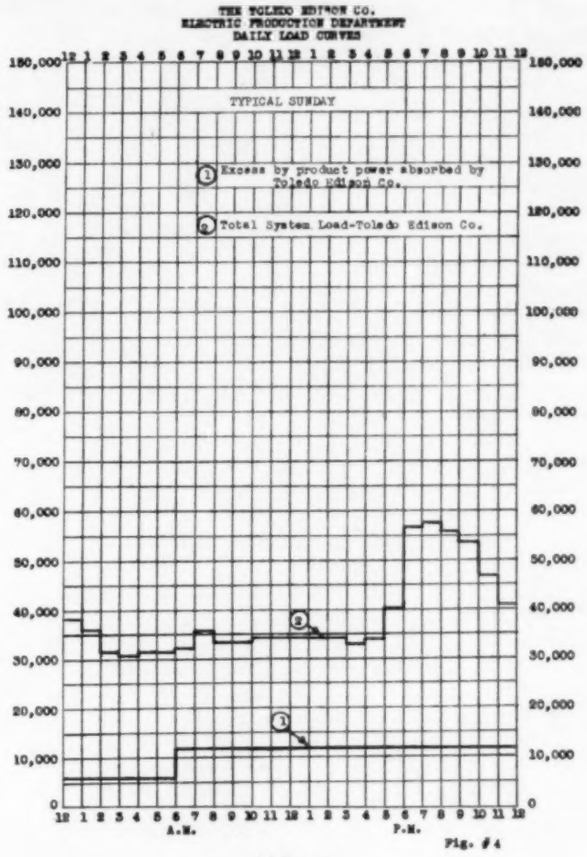


FIG. 4

Interconnection between the Duquesne Light Company and the Davison Coke and Iron Company

By G. E. DIGNAN† and R. L. KIRK*

The Davison Coke & Iron Company, engaged in the manufacture of coke, iron, and cement, is located in Pittsburgh on Neville Island in the Ohio River, about five miles down stream from the junction of the Allegheny and Monongahela Rivers. Because of the availability of excess blast furnace gas and of waste heat it was only logical for this company to install their own generating facilities. However, operating conditions were such that during certain periods it would be impossible to secure sufficient blast furnace gas to generate all of their electrical requirements. This meant that it would be necessary for them to install some coal fired boilers in order to be sure of sufficient steam to operate their turbines continuously at the necessary capacity.

Furthermore, if absolute continuity of service was desired, it would be necessary for the Coke & Iron Company to install a spare turbo generator. Even if their maximum demand of 7,000 kw. was handled by two 5,000 kw. machines and they could curtail operations to the extent of 2,000 kw. of load in case of failure of one turbo generator, it would still mean that under normal conditions the generators would only be partially loaded and would therefore not be worked to the fullest advantage. This meant that in order to provide the best operating conditions it would be necessary for the Coke & Iron Company to spend considerable capital for standby capacity.

On the other hand there would be periods when certain processes would not be in full operation, dur-

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† Chief Engineer, Davison Coke & Iron Co., Pittsburgh, Pa.

ing which the Coke & Iron Company would have available surplus energy which, if not utilized, would result in the waste of the blast furnace gas. Therefore, the ideal solution of the problem was an interconnection with the Duquesne Light Company system. This would enable surplus energy to be delivered when available, to the Light Company system, from which system emergency energy could be secured when needed by the Coke & Iron Company. This arrangement would not only save a considerable capital investment by the Coke & Iron Company, some of which, however, would be offset by the cost of the interconnection, but would supply the Duquesne Light Company with dump energy at a reasonable price, and at the same time connect to their system a new customer capable of taking large quantities of energy from time to time. Furthermore, this arrangement would conserve energy which might otherwise be lost.

It therefore became a matter of economics to determine the value of dump energy to the Light Company and of emergency energy to the Coke & Iron Company, the cost of which would enable both companies to profit by the transaction. In arriving at the value of the energy to the Light Company it was recognized that inasmuch as the quantity and time of delivery of the energy were uncertain and entirely in the hands of the Coke & Iron Company, it could not be considered firm power by the Light Company. That is, it could not be used to supplant generating capacity of the Light Company, and therefore the value of the energy could only be based on the generating cost and not on the total cost, which includes fixed charges on equipment. In

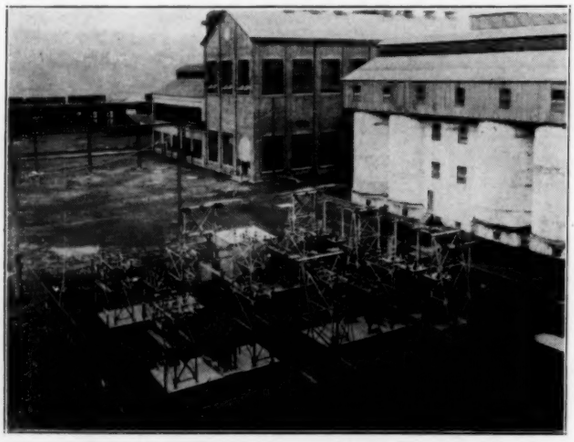

FIG. 1—General View of Substation showing Power Plant in Rear

other words, the value of the energy to the Light Company could only be based on the increment cost of generation, and not on the average cost. Upon careful analysis of operating costs over a long period of time the Light Company was able to arrive at its increment cost for the estimated quantities of dump energy to be received. This increment cost consisted mostly of fuel costs, with some little maintenance.

The cost of the dump energy to the Coke & Iron Company was also based on increment cost because no additional equipment was installed for the interconnection, power being delivered to the Light Company when not required by the Coke & Iron Company, and therefore the fixed charges could not be charged to the cost of this surplus energy. As their fuel costs were practically nothing, the increment cost was made up mostly of maintenance and some operating expense.

In arriving at a satisfactory rate, the Light Company recognized the desirability of the interconnection which would provide a customer with a rather large potential demand, and accordingly agreed to

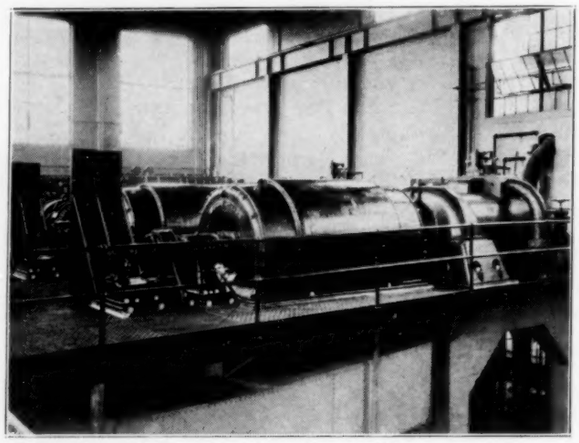

FIG. 2—View of Turbine Floor of Power Plant.

purchase the dump energy at a figure very close to their own increment cost. At the same time this interconnection will make possible the staggering of additional generating facilities on the two systems in the future, which should be financially attractive to both companies.

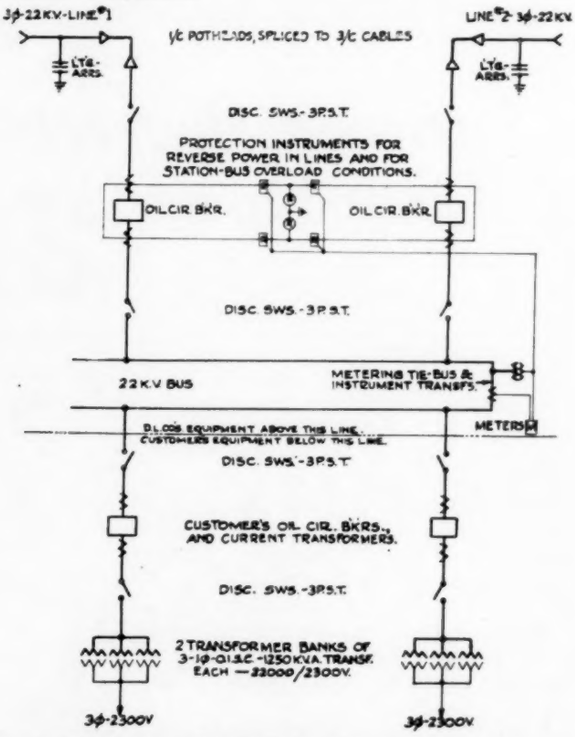

FIG. 3—Single line diagram showing that both incoming lines from the Light Company feed through suitable oil circuit breakers into the substation primary bus.

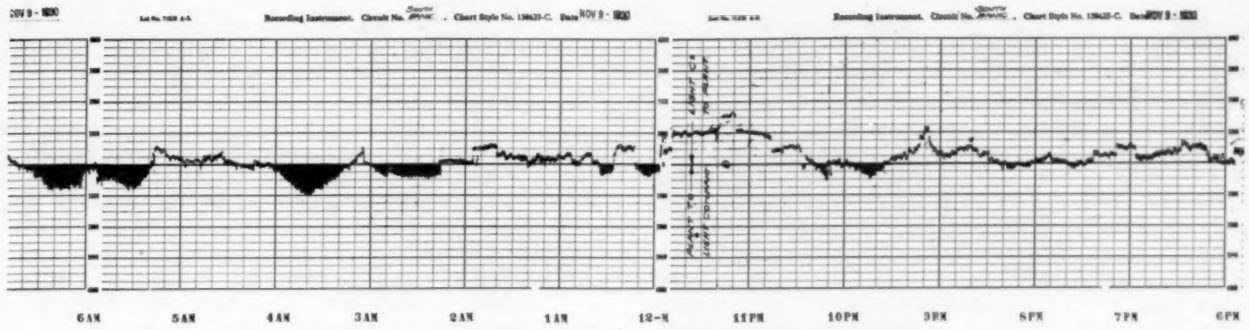

FIG. 4—Typical Daily Curve Showing Interchange of Power.

The contract covering service delivered to the Coke & Iron Company was based on the Light Company's standard wholesale rates, which included a demand and energy charge. The demand charge in this case was entirely logical, inasmuch as the Light Company stands ready at any time to supply any or all the Coke & Iron Company's requirements, and therefore must hold in reserve generating facilities for this purpose, while the dump energy is delivered to the Light Company on the when, as, and if basis.

On the above basis a contract was entered into which sets up definite rules and regulations by which the operation of the interconnection shall be governed. In addition to the usual contract clauses defining requirements and describing the necessary installation, the contract states that the adjustment of voltage and power factor within the limits of the equipment shall be under the control of the system operator of the Light Company, and that the Coke & Iron Company, insofar as possible, shall furnish the Light Company one week in advance a schedule of the approximate kilowatt hours of energy it expects to deliver to the Light Company each day during the following week.

The substation which forms the interconnection is of the outdoor type, known as a customer's loop substation, and is looped on what is known as the Brunot Island-Sewickley 22 kv. transmission line. One end of this circuit is fed directly from the Brunot Island Power Plant of the Light Company, and the other end from the company's Sewickley Substation through several other customer's loop stations on Neville Island. The single line diagram shows that both incoming lines from the Light Company feed through suitable oil circuit breakers into the substation primary bus. This bus is connected through oil circuit breakers to the primary side of two banks of transformers, each rated at 3750 Kva., 22,000/2200 volts, which transformers either step up or step down the voltage, depending upon whether or not power is delivered or received by the Coke & Iron Company. The secondaries of both banks of transformers are connected directly to the power plant bus in the power house. The unit type of bus structure is used for each bank of transformers and also for the substation's 22 Kv. bus.

A metering and control house is located at one side of the substation. In it are the metering and relay panels which operate the Light Company's equipment. The metering panel consists of three parts. The first one has two graphic meters, one of which is zero center and records incoming and outgoing kilowatts, and the other meter records the outgoing power-factor. The second metering panel contains two kilowatt hour meters in series, each with 15 minute interval demand attachment, one of these being a check meter, and a third meter which records reactive kilovolt ampere hours. The third panel, metering current delivered from the Coke & Iron Company to the Light Company, contains two kilowatt hour meters ratcheted to record outgoing power, one of these being a check meter.

When it is necessary to remove the incoming line breakers from service for maintenance or inspection, the breakers are automatically tripped from the control house adjacent to the substation through relays energized by a 24-volt battery. These breakers may also be electrically operated from the Coke & Iron Company's switchboard in their power plant through their own control switches energized by the Coke & Iron Company's 125-volt battery. All other breaker operations, however, are performed from the Coke & Iron Company's switchboard located in the power house. In the event of a high tension fault within the substation, these relays will open all four primary breakers—the Light Company's incoming breakers and the two between the station bus and the transformer banks—thereby de-energizing the 22 Kv. station bus.

The secondary leads from the two banks of transformers run directly to the power house switchboard bus which can be fed from either or both of these transformer banks. The two steam turbo generators, each of 6250 Kva. capacity, are connected to the power house bus through suitable oil circuit breakers, and each generator has its neutral grounded through a 900 ampere resistor. These generators are normally in operation and tied into the bus along with one bank of transformers. Power is either delivered or received depending upon the plant load and the available fuel supply. The interchange of energy is maintained up to the full capacity of one bank of transformers with periodical reports being made by the Coke & Iron Company operators to the system operators of the Light Company. In case it should be necessary to use the second bank of transformers due to limited generating capacity and heavy plant loads, the system operator of the Light Company is notified and arrangements are made to cut in the second bank of transformers. However, due to the fact that some time must elapse before this additional capacity can be cut in on the Light Company's lines, relays are provided by the Coke & Iron Company which automatically cut out certain of the plant motors classified as non-essential when the

plant load taken from the Light Company's lines exceeds 3750 Kva., the capacity of one bank of transformers. Likewise, in case the excess power available from the Coke & Iron Company's generators exceeds the capacity of a single bank in the substation, the Coke & Iron Company operators notify the Light Company, and similar arrangements are then made to take care of this excess dump energy. Very close co-operation is necessary and is maintained between the operators of the Coke & Iron Company's plant and the system operators of the Light Company. The procedure which is followed is very similar to that one used by the Light Company's own station operators and the system operator. During periods of considerable load fluctuation hourly reports are made by the Coke & Iron Company's operators to the system operators of the Light Company. Readings of all meters located in the meter and control house are taken and reported to the system operators every 24 hours. Also once each week the Coke & Iron Company furnishes to the Light Company the approximate kilowatt hours to be delivered to the Light Company during the following week.

Steam for the turbo generators is generated in two boiler houses, one consisting of two waste heat boilers located at the end of the cement kiln and the other containing six 860 HP. boilers, equipped to burn gas from either the blast furnace or the coke ovens, and one boiler at 860 HP. rating, with a chain grate stoker for burning coke screenings. The steam generated by the waste heat from the cement kiln is sufficient for about 90% of the electrical power required by the cement plant when in full operation. During the time that the furnace is in blast, fuel is available in an excess quantity for all plant requirements and this fuel is utilized when excess power is generated and delivered to the Light Company. At times when the furnace is not in blast, coke oven gas is burned under the boilers and sufficient of this gas can be had to carry the plant load in the event of failure of other sources of fuel.

Graphic watt meter curves taken while the blast furnace was banked, with the consequent loss of fuel from this source, indicated the real value of the interchange to the Coke & Iron Company. These curves varied from plus to minus throughout the day, showing that at times power was taken from the Light Company, relieving some of the load on the plant generators when either the plant load increases or the fuel supply decreased. There were also times when power was delivered to the Light Company due to the plant load decreasing or the fuel supply increasing.

During such times as power is being taken from the Light Company's lines, the operator by carefully watching the plant load, can reduce the non-essential loads and prevent the creating of a large demand. Since the interconnection was established, some minor changes in the operating schedule of several parts of the plant have been made. This has enabled the operators to control extreme fluctuations in the load and to prevent excess demands being created at the Coke & Iron Company's plant.

Continuity of service for a 700-ton blast furnace, 1500-ton coke plant, a 3000-barrel cement plant and power for compressing the surplus coke oven gas which is discharged some 20 miles from the plant is of first importance. Services for operating such a plant must be maintained 24 hours a day.

The interconnection between the Coke & Iron Company and the Light Company has proved itself to be of extreme value to the plant. This has been further demonstrated on several occasions when some of the plant generating equipment had to be serviced, and also from the standpoint of additional investment which would have been necessary to provide for standby steam and power generating equipment to take care of peak load conditions and the necessary overhaul and servicing of the equipment.

Electrically Heated Annealing Furnaces for the Steel and Other Industries

By J. C. WOODSON *

Annealing in general is not considered an electrical art. Most Electrical Engineers are, however, familiar with at least some annealing processes that form an indispensable part of the manufacture of electrical equipment, and the steady growth of annealing furnaces, electrically heated and controlled, makes this subject of increasing interest.

The present day status of engineering development is a result largely of our knowledge of, and skill with, materials in general and metals in particular. The advancement of this knowledge and skill has been directly connected with the development of correct heat treatment of metals and alloys.

These heat treatments form a long list, so that no attempt is made to cover them all in one short paper, although practically all are good applications for electric furnaces. We will treat of annealing furnaces only.

The term "Annealing" has been broadened out to cover a rather wide field of application such as "Full Annealing", "Process Annealing", "Normalizing", "Patenting", "Spherodizing", "Malleabilizing", "Graphitizing", etc. These different types or processes of annealing follow no definite specifications but appear to differ with various manufacturers and with materials to be annealed. Therefore this paper will be confined to specific stated materials and heat treatments.

For many years prior to the advent of scientific research into industry, steel manufacturers in general clung to the opinion and practice that heating metal to a red heat and cooling either in or out of the furnace constituted good and sufficient anneal,

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without reference to grain structure, measured hardness, surface conditions or electrical properties.

Within recent years certain industries, such as the electrical industry, wire manufacturers, strip and tube mills and the automotive industries, developed better and more reliable annealing practices. But the great bulk of raw metal from our large mills is, even today, still being either improperly annealed or is shipped to the user in the unannealed condition. The demands of large fabricating plants such as automobile plants and also the urge of close competition is bringing about a rather rapid, and in some ways remarkable, change in these conditions in that the large steel and metal mills are being compelled to produce at their plants, raw materials such as sheet, tubing, shapes, castings, etc., to meet definite and rigid specifications as to hardness, strength, grain size and structure, surface finish and condition. This trend is so pronounced and successful that it may be considered epochal in the metal industries, and within a very few years such will in all probability be universal practice. The user or fabricating plant will then be able to produce better and cheaper products than at present. Such refinements at the source of supply will increase with time, and represent the real potential market of the future for better manufacturing methods and equipment.

Since the late war great progress has been made in the development and application of electric resistance type furnaces to such trades as machine and machine tool builders, the automotive trade and the allied industries. These heat treating furnaces and machines are more or less familiar to all of us so will not be dwelt upon here. The improved annealing and normalizing practices here developed in these industries are now being passed on to the steel mills, and these processes, in most instances, either require or are more suited for electrically heated furnaces. These furnaces, while not fundamentally new developments, usually have to be designed specially for the application in question and a few representative installations will be studied in detail.

Brass Annealing:

The Brass Industry, one of the first to adopt electric melting, has not been so ready to accept electric annealing. There are perhaps not more than twenty-five or thirty electric installations for annealing at present in the United States, and these are on more or less special applications. The present annealing practice is essentially that of a quarter of a century ago or even older, wood fires still being used in many places, although modern gas furnaces are also numerous.

The annealing of brass sheet, shapes or parts is not a difficult operation. The permissible temperature variation is usually rather wide, allowing the use of fuel fired furnaces for a great many applications. It is also considered necessary by most operators today to pickle after annealing, which allows of great variations in annealed surface conditions. Some operators still contend that better anneal and better surface is obtained with wood fires than any other form of heating. This, however, appears to be more a matter of opinion than fact. In view of the above conditions, gas, because of its relative cheapness, is still the favored means of heating except for special operations, or for high grade product that demands uniform temperature distribution and close control.

Within the last two or three years progressive brass mills have been studying their heat treating practices. They recognize the advantages of electric heat but question the cost. To offset this and provide a better product, it has been proposed to anneal in the electric furnace in an artificial atmosphere which will give the desired finish and surface condition to the annealed work, thus eliminating scale, bad surface and the pickling and cleaning operations. There are now some six or seven such furnaces in several different brass plants in successful operation. Full cost data is not yet available but indications are that the overall annealing costs are lower than with former fuel fired equipment, and that the product is of higher grade.

There have been a few such installations in Europe, also and at least two furnaces annealing brass strip continuously in artificial atmospheres are in operation. These however, do not give the surface conditions obtainable in batch type furnaces. Further work along this line will no doubt remedy this deficiency.

What is termed as "rough annealing" of brass is carried on at temperatures from 950 to 1350° F. depending upon the analysis of the work and the results to be obtained. The permissible temperature variation is rather wide, being in the range of ± 35° to ± 40° F.

Finish anneal is usually at temperatures between 1050 and 1300° F. with a rather close temperature variation of between ± 5° to ±15° F. The types of furnaces used are box, tunnel, pusher, walking beam, roller hearth, conveyor and elevator. The economies to be expected are 18 to 26 pounds per K.W. hour and a survey of several plants indicate actual money savings of 75c to $2.50 per ton over the fuel fired equipment. Such savings on large tonnages results in returns on the investment as high as 50% per annum besides producing better products.

Copper

Annealing of copper in electric furnaces has been more or less common practice for a number of years. The types usually used are the box, conveyor and Kenworthy. This material is particularly well suited to electric furnace operation and the advantages are numerous. A steam atmosphere with water seals is generally used to prevent oxidation and scaling.

A few furnaces are now in operation using other gases with success. Some of these appear to be an improvement over steam and water as all tarnish and water stain is prevented. Copper is annealed at temperatures between 600 and 1200° F. and requires close temperature control and distribution. The variation should not exceed ± 10° to ± 15° F. Costs on copper annealing electrically do not appear to be so important as quality of product, as definite surface conditions must be obtained. This alone more than justifies electric furnaces in several plants investigated; in others reported cost savings are from 50c to $1.50 per ton over fuel fired furnaces. The economies obtained are from 20 to 30 pounds per K.W. hour. The material treated is usually sheet, strip, wire or tubing. The latter presents some difficulties as the interior of the tube must also be bright annealed and this necessitates special furnace design and methods of operation.

Other non-ferrous alloys such as nickel, nickel-silver, nickel-chromium are being annealed today in electric furnaces, both with natural and artificial atmospheres, at substantial savings in overall cost, and in some cases the results can not be duplicated in combustion furnaces. Reports of cost reduction on these metals vary from $1.00 to $3.30 per ton. The types of furnaces used are generally the same as used for brass annealing. The temperatures employed depend on the composition of the metal and results to be obtained. Control uniformity must be relatively close.

Aluminum Annealing

Sheet aluminum is annealed to relieve rolling strain and obtain the proper grain structure for drawing and forming. Aluminum castings are annealed to remove casting strains, refine the grain and improve machinability. The temperatures commonly employed range from 550 to 1000° F. Temperature control and uniformity must be very close, ± 5° F. often being required.

Another strict requirement of this metal is that the temperature gradient from heat source to work must be as small as possible to prevent over heating the extreme edges. Consequently special design and care of details is required. Under these conditions fuel fired furnaces are practically eliminated for aluminum annealing and electric furnaces are almost universally used. The types employed are box, pit, conveyor, car bottom and bell type. Oxidation of the metal during annealing is not so serious as with other non-ferrous metals and natural atmosphere is consequently used. The metal is soft however, and necessitates particular care to prevent scratching or marring of the surface. Great care must be exercised in the design of material handling equipment before and after the furnace as well as through the furnace proper to accomplish the desired result.

For pack annealing of aluminum sheet the furnace most suitable has been the car type furnace. A relatively large number of such furnaces are in use in the United States and Canada for this application. Tests on several such furnaces indicate a temperature distribution as close as ± 5° F. throughout the pack in some furnaces, and ± 7° F. on others. The dispersion rate on the heating elements is quite low, running between 3 and 5 watts per square inch of element surface. This is necessary to protect the edges of the sheets from local overheating. The doors of these furnaces are quite large, therefore they are motor operated and interlocked with the track raising mechanism so that the door can neither raise or lower unless the track is in the proper position. Besides the two control thermocouples in these furnaces, there are also several couples located in each charge and other parts of the furnaces for indication of temperatures at all times during a heat.

Electric furnaces are in operation for annealing aluminum structural shapes up to 90 feet long. Electric furnaces for annealing fabricated parts such as aluminum chairs, furniture, airplane parts, etc., require such close temperature distribution that circulating fans must be employed in the furnace chamber to be sure all parts are in an atmosphere of the same temperature. One such furnace is now under construction using 32 large fans in a single chamber. Such circulation of the air at low and medium temperatures also tends to speed up the heating cycle.

An interesting large furnace is now being built of the roller hearth type for heating aluminum billets between passes. This furnace is 63 feet long 25 inches high and 85 inches wide inside. The overall length is 132′ including roll table and has 62 special alloy polished rolls forming the hearth. These rolls, as well as the doors, external roll tables, temperature controls and indicating lights are all controlled by one operator at a control desk so located at the side and elevated above the furnace that he can see all operations pertinent to the work. An unusual feature of the furnace is a special arrangement of indicating lights down the top of the furnace which indicate to the operator the exact location of all billets in the furnace at all times. At the operator's desk are auxiliary indicating lamps which detect and indicate any failure of the main indicating lamps or their circuits. Electrical interlocks are provided to prevent jamming the doors with billets, in or out of the furnace. Electrical interlocks are also provided to prevent operating adjacent rolls in opposite direction at the same time. All rolls operate through electric magnetic clutches so that it is possible to disconnect or stop any of them at any time. All rolls are reversible. Accurate cost data is not available at present but tests indicate the economies to range from 10 to 20 pounds per K.W. hour depending on conditions.

Annealing of Steel:

The field of steel annealing is so diverse and so comprehensive that it would be impossible to cover all applications in this short paper, so reference will be made to a representative list only.

Castings and Forgings:

Iron, carbon steel and alloy steel castings are being annealed in electric furnaces more and more each year. The types of furnaces used are generally the car bottom, pusher or conveyor (for small parts) box type, elevator and bell type.

The object of such heat treatment is generally ageing, relief of casting strains, improving machinability and securing proper grain structures. These results can be secured with such certainty, uniformity and regularity in the electric furnace that lower priced fuels are often ruled out in face of the apparently higher operating costs.

A recent important step has been taken in the field of malleable castings. The older fuel fired process ordinarily consumed six to eight days with very low economy as the parts were packed in sand and scale in heavy cast boxes. By the modern process employing electrical furnaces, proper malleabilizing is obtained in thirty to forty-eight hours and without the use of packing boxes or packing materials. Such advances as these are of true economic value to Industry and the Country as a whole.

The economies for casting annealing runs from 8 to 15 pounds per K.W. hour depending on the cycle employed, type of furnace etc. The temperatures range from 950° F. to 1650° F. for carbon steel and to 1950° F. for manganese steel.

Likewise there is a rapidly growing demand for electric forging annealing equipment. In such industries as the gear and axle plants, automobile plants,

ball bearing manufacturers, etc. such furnaces have been in use for several years past, and have fully demonstrated that the tangible advantages outweigh the higher fuel cost, and result in finished parts at lower overall cost than with fuel fired furnaces. The reduction in rejects and ease of machining often pay the entire power bill. Definite cost figures can only be given on specific applications as the heat treating cycle varies with each steel and almost every manufacturer. Economies run from 10 to 18 pounds per K.W. hour.

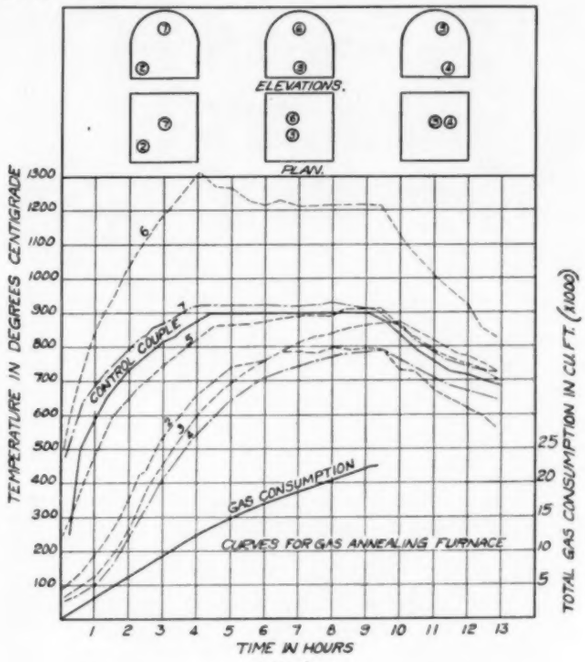


FIG. 1.

As the object of this paper is to describe and point out the characteristic advantages of electric furnace equipment some actual examples will be of interest. In this connection, tests were run within the last few months in the Pittsburgh District on a large car bottom, gas fire furnace for annealing steel castings at the Foundry.

The furnace was of the latest and most modern type and represents much more than the average, so far as gas fired furnaces are concerned. The product was variable and unsatisfactory. Tests as run by the owners and operators themselves showed clearly the trouble. This data is shown in Figure 1. Repeated attempts to correct this distribution has had but little effect so far.

A second test of a modern gas fired furnace for annealing automobile crankshafts within the last few months is shown in Figure 2. This test was run by the Gas Company engineers in an effort to prove that their furnace would control within $\pm$ 10°C. The chart tells its own story. Both these tests, run on modern insulated gas fired furnaces by combustion engineers, undoubtedly show results far superior to those ordinarily obtained in every day practice with old obsolete furnaces and careless operators. Figure 3 shows the results of tests on a pit type furnace electrically heated, which was one of several made for annealing wire and strip steel. This chart was selected because of the fact that uniform distribution in a vertical pit type furnace is very hard to obtain and this chart shows the possibilities of electrically heated equipment. No contention is made that all electric furnaces have perfect or even good distribution, as this of course depends upon the design engineers' skill and experience. With the proper design, however, electric furnaces will show results impossible to obtain otherwise.

There have been published from time to time dissertations on this subject wherein the author stated the opinion that the source of heat was not important but that with correct furnace design any source was suitable. They may be right, but in view of the tests shown in Figures 1, 2, and 3 it is felt that "correct" furnace design with some fuels

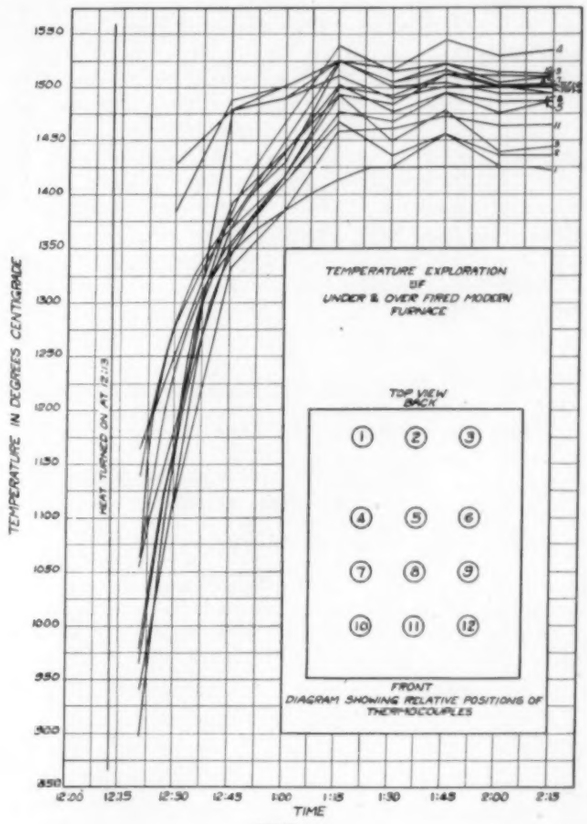


FIG. 2

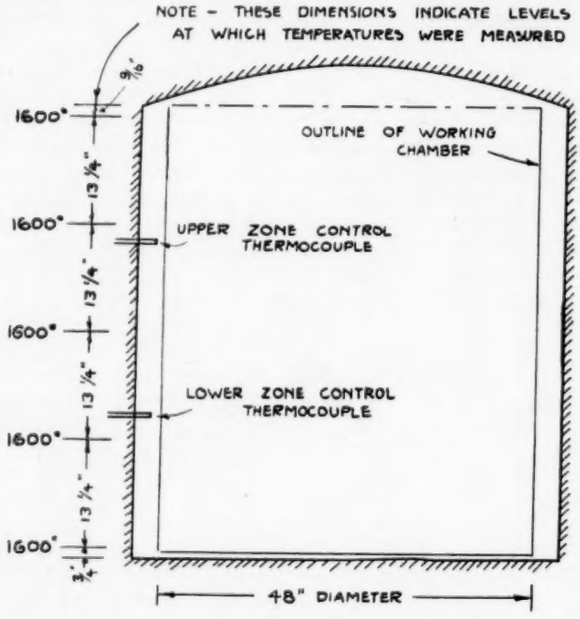
and for some applications is practically unattainable. The author has personal knowledge of numerous applications of heat treatment that apparently can not be successfully accomplished by means other than electric heat.

A great variation in furnace design has been followed to meet exacting conditions of different annealing cycles. For continuous operations, heavy walls of fire brick and insulation are used. For intermittent cycles, light walls of semi-refractory bricks and insulation are used.

Definite rates of cooling are obtained by means of cooling ducts or pipes through the chamber or charge. With "double anneals" the cooling rates are just as important as the heating rate. So far there has been no occasion to apply artificial atmospheres to electric furnaces for casting and forging annealing, though unquestionably such will come later to obtain some special results.

Structural and Fabricated Shapes

More recent is the advent of electric annealing of structural shapes and large welded and fabricated parts. The steel mills are experimenting with such processes on rather large scales and even railroad rails are being annealed, both in Europe and the United States, to determine the advantages of heat treatment. Large welded shapes such as tanks, motor and generator frames, turbine parts, etc., are



CIRCULAR PIT TYPE FURNACE
TEMPERATURE DISTRIBUTION
(EMPTY)
60 K.W. 220 V. 1 ϕ

FIG. 3.

now annealed to relieve welding stresses and produce the proper grain structure to give maximum strength and toughness. Furnaces for this practice are usually of the car bottom type to facilitate loading and unloading, as the parts are quite heavy and require a crane for handling. Such a furnace is shown in Figure 4. This furnace has heat on all sides including the door, thereby insuring uniform heating to all parts of the charge simultaneously. Furnaces of this character have been built by one Company up to 65 feet inside length and 3000 K.W. installed capacity for annealing large still tanks. Another Company recently installed an overhead conveyor electric furnace for annealing and enamelling large pipe, having an installed capacity of over 12,000 K.W. in one chamber. As the steel industry comes to the general heat treatment of shapes on large tonnage basis, such furnaces will be common rather than exceptions. Cost data on these large furnaces are not available but in all instances to the author's knowledge, the users feel the results obtained justify the investment. In some cases these results can not be secured any other way, regardless of cost.

Wire, Strip and Sheet Annealing

The annealing and heat treating of steel wire for bridges and similar applications has been, until recent years, done in either sealed boxes in fuel fired furnaces or fuel fired lead pots. One of the largest makers of this class of material has installed large electrically heated lead bath furnaces, and heat treats or "Patents" his wire continuously, ten or twelve strands running in parallel through the lead at once.

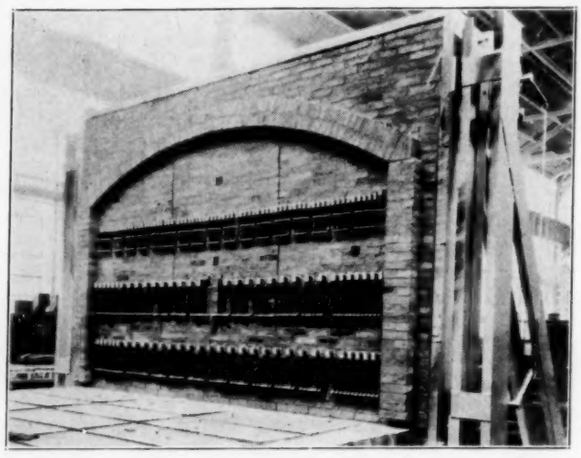


FIG. 4.

Other heat treating operations such as hardening, quenching and drawing follow the same scheme. His product is much superior to that of former methods and the overall cost is less. Similar equipment is also used for narrow steel strip such as saw blade stock, measuring tape stock, etc. See Figure 5.

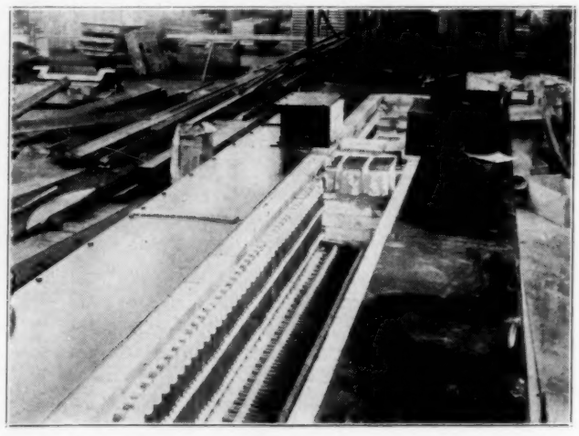


FIG. 5.

In the cold rolled steel industry, large tonnages of low carbon steel strip are annealed, usually in large cast iron boxes in coal or gas fired furnaces. The common practice generally shows approximately two ton of box, base and sand heated for each ton of steel heat treated. This is, naturally, rather poor economy and the product is none too good due to temperature variations and non-uniform heating and cooling. During the last three years the Westinghouse Company has worked out designs of electric furnaces and processes which produce practically 100% uniform and acceptable products, bright annealed, and at actual cost savings of 75c to $2.00 per ton over existing methods in the same mills.

These electric furnaces are of the "Bell" type, and are designed to anneal cold rolled strip in the coils to obviate uncoiling and recoiling and also as a further assurance that the surface will not be scratched. Figure 6 shows a view of one such

furnace already built. The coils are stacked one on top of the other on the base as shown, and a sheet metal hood is then lowered over the charge. The loaded base which is mounted on wheels is pulled by a motor operated car puller, into position under the furnace proper or "Bell." This bell which is kept hot at all times is lowered over the charge in which position it fits snugly on the base. The outer edges of the furnace shell and hood dip into a liquid seal outside the furnace to prevent escape of the gas used as an artificial atmosphere under the hood. This gas is a treated, cheap, by-product gas such as blast furnace or coke oven gas and is passed through pipes in the bases over the charge continuously while heating and cooling to prevent surface oxidization. After a charge is up to temperature (1350° F. to 1600° F., depending on work) the furnace bell is raised and

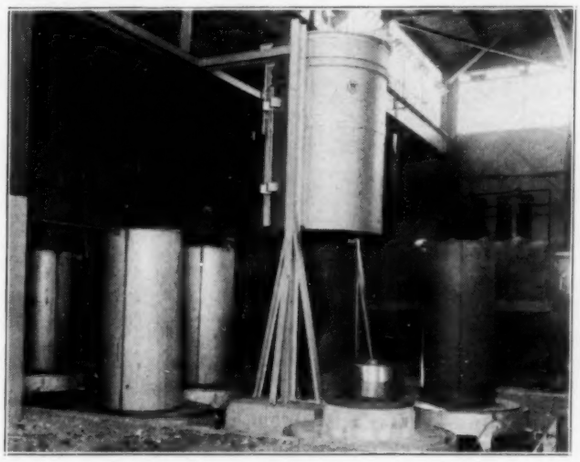


FIG. 6

the base, hood and charge are moved out on the track to cool and a fresh charge pulled under the bell. This operation requires but two or three minutes and effects great economy as the operation is practically continuous and the loss of heat from the bell is very small. A noteworthy feature of this design is the use of a center heating element that allows the interior of the coils to be heated at the same rate and at the same time as the exterior. This center heating element is so designed as to give vertical uniformity of heating effect and also to disperse heat to the interior of the coil at the same heat density as the outside of the charge receives. Tests with a dozen thermocouples throughout the charge indicate the distribution to be as close as ± 5° F. The average charge weighs 6000 pounds and the economy is from 11.5 to 13.5 pounds per K.W. hour at 1350° F., depending on conditions.

Actual test runs on both gas fired and electric furnaces extending over a period of several months indicates the following operating costs for the two methods.

	Cost per ton Gas Fired Furnace	Cost per ton Electric Furnace
Labor Maintenance Miscellaneous	3.05	1.45
Fuel	2.15	1.40
Total per ton	5.20	2.85
Saving Electric over Gas Furnace		$2.35

Such savings with companies making 300,000 to 600,000 tons a year amounts to real money and will show a return on the furnace investment of approximately 200%. These savings do not include such items as "better working conditions," "better product," "fewer rejects," etc., but are actual operating costs.

To the above figures should be added the cost of the reducing gas which also is less for the electric furnace, but since this cost will vary with the gas used, geographic location, product treated, etc., it will be disregarded here. The above figures are based on 550 B.T.U. city gas at 35c per M. and electricity at .8c per K.W. hr.

It was also found that the heat treating time was reduced from 72 hours per run to 35 hours, due mainly to the fact brought out above that with the gas furnaces the charge represented only one-third the total weight to be heated, whereas in the electric furnace the charge is over 75% of the gross weight.

Similar furnaces have now been installed in two other large cold rolled mills. Recent checks on production costs show the same ratios as given above and in each instance the quality of work produced was superior to the gas fired product and the rejects practically nil.

A distinct advantage of the semi-continuous bell type of furnace installation is that, with a number of units, great flexibility can be secured to meet variable production schedules. By merely shutting down one furnace after another, with decrease in orders, maximum efficiency will be obtained as remaining furnaces will continue to operate at full capacity. This is not possible with one or two large continuous type furnaces that must operate very inefficiently at light or variable loads.

Pack annealing of large size high silicon sheet and punchings has now been developed to a rather fine degree. The most suitable furnace for such work is, beyond question, the large rectangular bell furnace as with several bases per furnace the operation can be practically continuous and economical.

Such furnaces to a considerable number are now in operation in capacities up to 60,000 pounds per charge.

Here also the rate of heating and rate of cooling are as important in securing the proper magnetic qualities as uniform temperature distribution and automatic control. These furnaces can be used with or without artificial atmospheres.

Bright Annealing in Artificial Atmospheres

The increasing and incessant demand for better surfaces on annealed mill and fabricated metal has resulted in a great deal of experimental and research work being done on artificial atmospheres for furnaces to secure these results. On the cold rolled strip furnaces mentioned above, partially cracked and purified coke oven gas is being used with success. In another place, treated blast furnace gas is also used. Such atmospheres are really not "reducing," that is, they do not reduce any scale or oxides which may be on the sheet before annealing but merely

prevent the formation of scale or oxide during the heating and cooling cycle. For mill anneals, this is usually all that is required to produce satisfactorily clean metal. However, on other grades of metal a higher finish is desired and different artificial atmospheres are necessary. The Westinghouse Company and others have done a great deal of research work along this line. The results, briefly, are that several related gases or combinations of gases can be used successfully for this purpose, such as dissociated ammonia, dissociated butane, dissociated natural or city gas (with or without water vapor), hydrogen and dissociated methanol or wood alcohol. The order given is approximately the order of desirability from a cost and utilitarian standpoint, for the majority of bright annealing applications. Of course, the particular results to be obtained, the cycle employed, the metal heated and local economies enter into the selection of such a gas. For instance, the blast furnace and coke oven gas mentioned in connection with bright anneal of low carbon cold rolled steel would not ordinarily be used on high carbon tool or roller bearing stock, but rather cracked butane, which, when properly controlled, can either add, subtract or hold constant the surface carbon content so important with such steel. For the non-ferrous metals, i.e., brass, copper, nickel, etc., other gases are required, depending on the metal and results to be obtained. The use of such artificial furnace atmospheres has necessitated rather complete redesigning of furnace shells and structures as these gases are quite light and thin at high temperatures. As most of these gases are explosive, the technique of safely handling the equipment when hot has had to be developed.

As annealing in artificial atmospheres is in its early development stages still, possibilities along this line are not known. However, certain surface conditions can be obtained that reduce the number of subsequent operations and greatly increase die life and reduce machine work. Recent investigations seem to indicate that, at least on some metals and alloys, the grain, size, and structure are affected by the atmosphere during heat treatment. If these findings prove to be correct a great deal of development on artificial atmospheres for this purpose alone may be expected.

In addition to securing clean annealed surfaces otherwise unattainable, these artificial atmospheres are showing a possibility of reduced cost of product by reducing or eliminating the usual pickling, washing and drying operations.

Recent extensive tests on high grade tin plate stock in production lots demonstrates at least the possibility of going directly from the annealing furnace to the tin bath. Present results along this line are quite encouraging but further research work will undoubtedly be necessary to perfect such a process. The possibilities along this line, in the whole industry, are very extensive.

Bright annealing of the high chromium series such as 18 and 8 is also attracting considerable attention due to the rapidly increasing demand for this new metal. This steel cannot be annealed as simply, even in artificial atmospheres, as the carbon steel due to the fact that the rate of heating and especially the rate of cooling must be rapid and under constant control. The annealing temperatures are also rather high, being 1900 to 2000° F. For these steels, artificial cooling is necessary.

Future Trends

It is always difficult and hazardous to attempt to predict what the future will bring in a rapidly expanding industry, so only a few of the present tendencies and possible developments will be enumerated for what they may be worth:

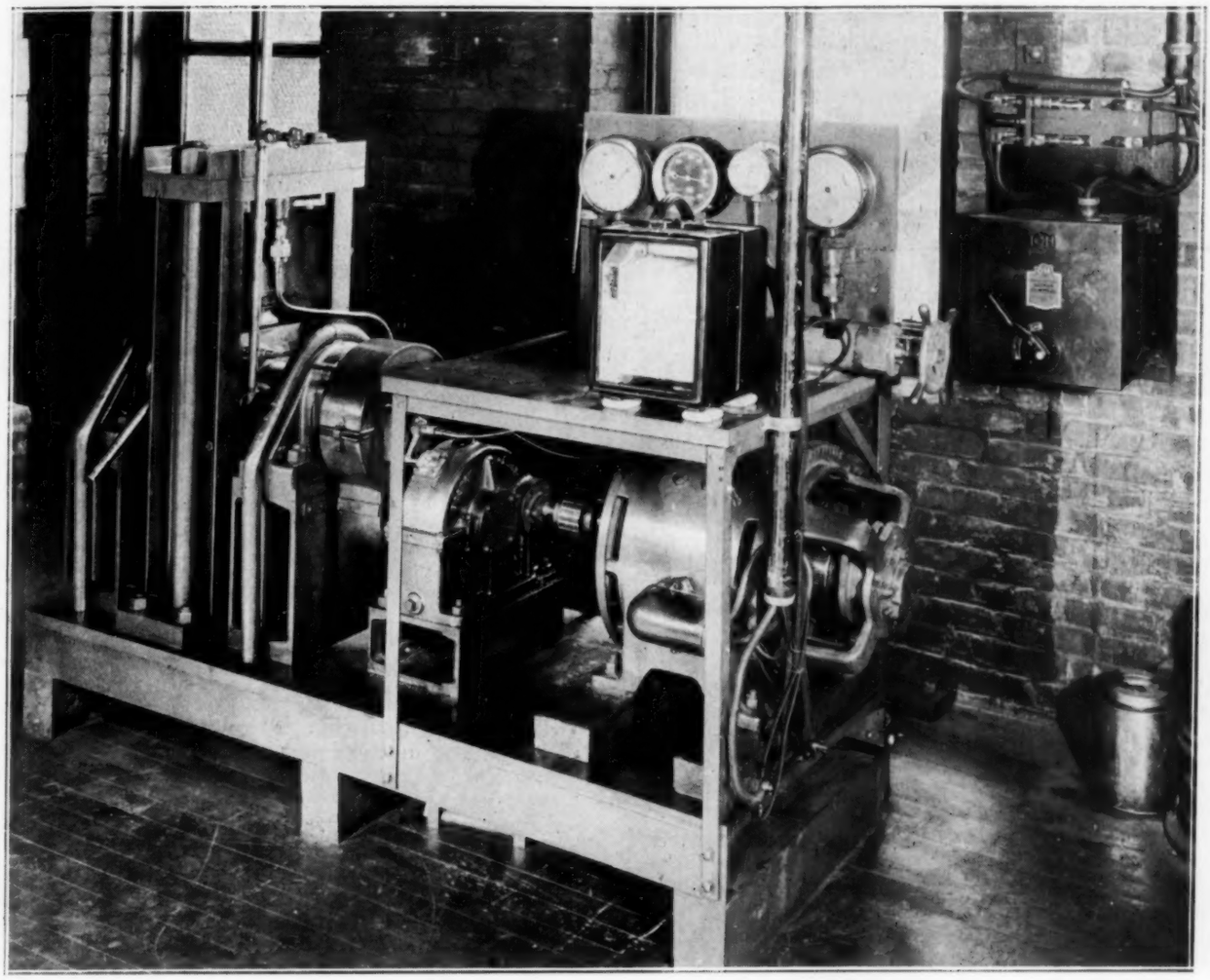
FIRST: A rather rapid and extensive expansion of electric annealing, bright and semi-bright to the wire, strip and sheet mills generally. It is believed that this will be necessary from an economic and competitive cost standpoint if from no other. These economies result from lower maintenance, lower operating costs, shorter cycles, better products, fewer subsequent operations, long tool and die life, fewer rejects and reruns, etc. These are actual tangible and measurable quantities and need not be the subject of opinion or speculation.

SECOND: The use of artificial furnace atmospheres to secure special and better results will in all probability be more generally adopted throughout the steel and metal trade. Especially will the near future see it adopted in fabricating and manufacturing processes purely as an economic measure to eliminate unnecessary operations.

THIRD: There will be developed more of the large continuous electric furnaces for sheet annealing and normalizing, and with artificial atmospheres. A great deal of engineering thought has already been put on this subject, but as yet a design generally suitable has not been evolved. One or two applications have been made of overhead conveyor furnaces such as those now used for vitreous enameling, but these are only partially successful where bright anneal is considered. Successful small electric annealing furnaces for small parts are numerous now, but these designs cannot be extended to the sizes required for large tonnages of sheet and strip.

FOURTH: There will be a rather extensive development and application of the principle of inductive heating to numerous heat treating processes now considered unsuitable. Among these, will be annealing and normalizing of sheet and strip, perhaps continuously and rapidly, such as between passes in the mill. Annealing of structural shapes and especially tubing by this means is certain to come. Some work along this line has already been accomplished, with more to follow shortly. This work is still in its experimental stage and is not yet ready for the market. A few years more may see this principle so developed as to be attractive for both high and low temperatures.

It is unlikely that there will be much of a revival of the direct heating processes such as the "Snead Process" of passing current directly through wire, strip tubing, etc. While this method possesses attractive features, its application is fraught with control and practical difficulties of such character as to preclude its very general adoption as far as we can now determine. The future may of course eliminate some of these shortcomings and further develop the advantages.



Lubricants and Bearing Test Machine

By E. S. GLAUCH*

The testing of lubricants for heavy duty equipment such as found in Steel Mills has largely been done on the equipment which was to be lubricated.

This method is very satisfactory at times while at other times has been found unsatisfactory and very expensive. This is especially true if the lubricant being tested fails and bearings are scored, requiring their removal, thereby causing a loss in production.

To avoid the necessity of conducting such tests on production equipment, the writer felt it would be advisable to do this testing on some equipment or machine on which actual load and operating conditions could be duplicated.

After investigating various testing machines on the market it was found none met the conditions such as encountered on heavy duty steel mill equipment.

The writer designed a special machine which is shown in accompanying illustration. This particular machine was designed so that a load up to 37,300 pounds could be placed on the bearing on which either lubricant or bearing is being tested. This load would be equal to approximately 2,000 pounds per square inch of bearing surface. Should heavier loads be desired machine could be designed to take care of any load required.

Lubricant can be applied in the manner it would be, if used on production machine or mill. Speed can be varied and loads applied to suit. Water cooling is also provided. The various instruments such as pressure gauges, thermometers, tachometers, together with graphic watt meter for obtaining results all can be plainly noted in illustration.

Tests made on this machine indicate which bearings or lubricants tested are most suitable for conditions under which they are to be used in actual service.

*Mechanical Engineer, Joseph Dixon Crucible Company, Jersey City, N. J.

CONTROL MANUFACTURER'S COMMITTEE MEETING

(Continued from Page 104)

locks, some being shown to the right and left of the contactors, and others below the contactor. The present method indicates the position of the interlock with respect to the mechanical attachment which operates it.

The discussion next was on various relays in use today on mill control applications. No attempt was made to discuss any one type due to the many different forms, such as normally open, normally closed, time delay, single and double coil relays.

Various letters and numbers are used on contactors composing a control panel. For example, the General Electric Company use 1R, 1F, 2R and 2F for reversing contactors and P, 1A, 2A, 3A for the plugging and three accelerating contactors respectively. Cutler Hammer uses 1F, 2F, 1B, 2B, 2R, 3R, 4R, 5R for the reversing, plugging and accelerating contactors. Westinghouse number their contactors while the Electric Controller and Manufacturing Company use R, RR, F, FF for reversing contactors and 2R, 3R, 4R and 5R for accelerating contactors. Various lettering is also used on relays. The representatives present saw no reason why one set of symbols could not readily be used.

Mr. Fleming stated he was a member of a standardization committee of the National Electrical Manufacturers' Association and at the present time was about ready to start work along the lines discussed. A standard rating of contactor has already been worked out, but of course will not be effective until new lines of contactors are developed.

Each one of the representatives did not express any objection to the plans for standardization work. Mr. Bowers and Mr. Kennedy stated it would enable them to more readily understand diagrams of competitors when being asked to quote on special equipment which one manufacturer already had in service.

There was quite a discussion on the types of wiring diagrams used. The chairman claimed that very frequently the wiring diagram was too small. For office work where a diagram could be kept clean there wasn't any objection to same, but in the field where the diagram became even slightly dirty same was very hard to trace, resulting in delay in getting the control equipment into operation due to mistakes and frequent attempts to get into communication with some one who was more familiar with diagrams. There was also a discussion on front and rear view diagrams. Practically all the companies with the exception of Cutler Hammer, furnish rear view diagrams. There are good arguments for each type of diagram. There was also a discussion on the advisability of placing elementary control and power schemes on the wiring diagrams.

In conclusion, in view of the fact that the chairman was the only operating man present, at the suggestion of Mr. Kelly it was decided to hold a meeting with some operating men in the near future, to determine just what they consider should be standardized.

(Signed) H. H. ANGEL, Chairman,
Control Symbol Standardization Committee.

MINUTES OF STANDARDIZED SYMBOLS FOR CONTROL APPARATUS MEETING TUESDAY, JANUARY 13, 1931 HOTEL STEVENS, CHICAGO, ILL.

The following active members were present:

J. J. Booth, Chairman, Superintendent Electrical Department, National Tube Company, Gary Works.

A. Whitcombe, Assistant Electrical Engineer, Freyn Engineering Company, Chicago, Ill.

F. Kittredge, Electrical Engineer, Illinois Steel Company, Joliet, Ill.

John Wagner, Electrical Engineer, Acme Steel Company, Chicago, Ill.

William Anderson, Ch. Electrician, Sellers Manufacturing Company, Chicago, Ill.

Frank A. Wiley, Electrical Engineer, Wisconsin Steel Company, South Chicago, Ill.

H. E. Davis, Ch. Electrician, Interstate Iron and Steel Company, Chicago, Ill.

Fred W. Acker, Assistant Ch. Electrician, Inland Steel Company, Indiana Harbor, Ind.

P. J. McGrane, Ch. Electrical Department, Railway Steel Spring Company, Chicago Heights, Ill.

W. S. Hall, Superintendent of Engineering and Construction, Illinois Steel Company, S. Chicago, Ill.

F. O. Schnure, Electrical Superintendent, Bethlehem Steel Company, Sparrows Point, Md.

J. F. Kelly, Managing Director, A. I. & S. E. E.

The Minutes of Philadelphia Section meeting were read by the Chairman. After the reading of these Minutes, the meeting was turned over to a general discussion covering wiring diagrams and symbols for auxiliary control used in steel mills.

Every individual present contributed in the way of suggestions and the following are the results of some two hours discussion. These suggestions are tabulated in the order in which they were given and discussed at the meeting.

All power lines should be shown much heavier than the manufacturers are showing them at the present time, in order that they can be distinguished from the control circuit. The wiring diagrams should be complete in every particular showing main and control circuits. In addition to the main wiring diagram, there should be a schematic diagram covering main power circuit and also schematic diagram showing control circuits. As stated above, the necessity of distinguishing between power and control lines was much emphasized.

There was considerable discussion on the method of showing contactors, interlocks, on wiring diagrams, and whether interlocks should be shown on right or left hand side of the contactor, or bottom. It was decided that the preferable place for showing interlocks was on the bottom of the switch, with a definite standard symbol for indicating normally open or normally closed circuits. It was brought out very forcibly that manufacturers should agree on a definite symbol for normally open or normally closed contactors, as it is very apparent that at the present time there is some discrepancy in the symbols adopted.

It was also recommended that the manufacturers be more explicit in the symbols which indicate parts of contactors that are alive or current carrying parts, and those insulated and non-carrying parts. This particular point was the subject of considerable dis-

cussion, as in many instances on present nomenclature it is hard to distinguish live from non-carrying parts, even though all wires are directed to the same point. It was also recommended that all diagrams be made up in rear view form. Some manufacturers at the present time make them front, others rear view. The common consensus of opinion was the rear view was preferable.

It was also recommended that in so far as possible, it is preferable for manufacturers to adopt the same scheme for indicating contactors and that in so doing a very definite distinguishing mark be made between normally open and normally closed contactors. Also there should be a common method adopted for showing the shunt coil, operating contactors. It was recommended that the back of the panel diagrams should follow the actual wiring on the board and that the lines on the diagram should be in so far as possible, in the same relative position as on the back of the board. The committee realized that wiring diagrams are first made up by the Engineering Department then the physical dimensions of the board are worked up. But it was the consensus of opinion that the two could be made to conform more readily than they do at the present time and make them much easier to follow. In many cases the one looking at the wiring diagram and the actual back of the controller panel would find it hard to recognize that they are supposed to be the same.

It was also recommended that diagrams be made larger than at the present time as some manufacturers make them very small and hard to read and distinguish between normally open, normally closed contactors, interlocks, etc. Also that the wiring diagrams should not only carry general wiring diagrams, but power scheme, control scheme, resistance diagrams and resistance value in tabulated form. It was felt by the committee that possibly the size of 16" x 21" should be a little larger.

In many instances in tracing both the main power lines and the control lines they are not properly marked, or in other words, too much is taken for granted, so far as general marking is concerned. It was deemed advisable and even necessary that the lines should be followed through conduit, piping, wiring to switches, etc., and marked at each and every junction in order that anyone reading diagram could follow the individual line from source to terminals. It was also recommended that location of terminal boards should be in so far as possible, standardized by all companies. This would enable the purchaser to bring up his conduit at approximately the right location when he is working from the dimension diagram of the panel. It was felt by all concerned that if these suggestions in a measure could be carried out and adopted by all manufacturers it would not only be of material assistance to the manufacturers, but of untold assistance to the operating men in the field.

Index of Proceedings of the A. I. & S. E. E. and Iron & Steel Engineer for Year 1930

The following index for the year 1930 of the activities of the A. I. & S. E. E. has been compiled for the purpose of providing for the engineers of the Iron & Steel Industry a yearly reference and guide of electrical, mechanical, combustion, lubrication and safety practices.

The index is catalogued as follows: 1st. Authors, who represent the leading engineers of the Iron & Steel Industry. 2nd. Subjects of Papers that cover practically all engineering in the Iron & Steel Industry.

A careful analysis of this index will lead to the conclusion that the A. I. & S. E. E. has performed a highly specialized engineering service of lasting and inestimable value to the Iron & Steel Industry.

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ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS CONVENTION AND IRON AND STEEL EXPOSITION

JUNE 15-16-17-18-19, 1931

ELECTRICAL, MECHANICAL, LUBRICATION, COMBUSTION, SAFETY ENGINEERING DIVISIONS, AND WIRE & WIRE PRODUCTS EXPOSITION—CLEVELAND AUDITORIUM

ALL TECHNICAL SESSIONS—CLEVELAND AUDITORIUM
ALL SOCIAL FUNCTIONS—CLEVELAND AUDITORIUM
ALL ACTIVITIES UNDER ONE ROOF

Electrical Equipment to Operate the Blast Furnace Skip Hoist†

By C. P. HAMILTON*

(1) General Discussion.

During the past four or five years, the trend in furnace construction has been toward greater output, and as a result, the burden on the skip hoist has increased accordingly. Today, stacks having an output of a thousand tons of pig are common. To obtain this output, it requires approximately thirty-five hundred tons of material—iron ore, coke and lime stone—to be fed into the stack in a like period, and the responsibility of handling this burden, day in and day out continuously, and at a fairly uniform rate, as long as the furnace is in service, is on the skip hoist. This requires a highly dependable equipment in every respect.

The increase in furnace sizes has also required that the hoist operate with better time efficiency. This means that the skip speeds are higher, and that uniform operating speeds—both full speed and dumping speed—are desirable regardless of the load in the bucket. Skips are now operating at speeds in excess of 600 F.P.M., whereas, just a few years ago, 400 F.P.M. was considered about as far as necessary. Increased hoisting speeds, however, is not the complete answer to increasing the capacity of the hoist or saving time. It is frequently assumed, that a given hoist can deliver more material in about the same ratio as the speed is increased. This is not the case, however, as may be shown by the following example:

An operating cycle based on a speed of 400 F.P.M. will be about as follows:

Accelerate to full speed	4 seconds
Run at full speed	25 seconds
Retard to dumping speed	3 seconds
Run at dumping speed	6 seconds
Stop	1 second
Total operating time	39 seconds

With a skip speed of 600 F.P.M., the cycle would be as follows for the same hoist:

Accelerate to full speed	5 seconds
Run full speed	15 seconds
Retard to dumping speed	3 seconds
Run at dumping speed	6 seconds
Stop	1 second
Total operating time	30 seconds

In other words, an increase in speed of 150% only increased the output 130%. An examination of the above time cycles shows the reason for this difference is due to the lower percentage of full speed operation at the higher skip speeds.

Uniform operating speeds, regardless of load, becomes more important as the skip speed is increased. If one trip takes 30 seconds and the next, with a heavier load, takes 38 seconds—which is not at all unusual—the daily capacity of the hoist is reduced close to 10%. As a more concrete example, large size stacks require about 45 trips per hour, or 1080 trips per day. If five seconds is gained by maintaining the same operating speed each trip, the capacity of the hoist would be increased by about 22 trips per day or over 2 per cent.

In addition to uniform operating speeds, close adjustment of the slow-down points; operating at as high dumping speed as practicable; maintaining high rates of acceleration and retardation; and quick loading of the buckets are all elements that should receive attention in order to get the most out of a given hoist.

(2) Types of Electrical Equipment.

There are six general types of drives that may be considered in selecting the electrical equipment as follows:

(A) A.C. two-speed motors,
(B) D.C. single-speed, one-motor drive with rheostatic control,
(C) D.C. adjustable speed, one-motor drive with rheostatic control,
(D) D.C. single-speed, two-motor drive with series parallel rheostatic control,
(E) D.C. single-speed, one-motor drive with Ward-Leonard control,
(F) D.C. single-speed, two-motor drive with Ward-Leonard control.

(3) General Operating Conditions to be considered.

A thorough study of each of these methods of driving the hoist should be made on the basis of:

(A) Reliability,
(B) Maintenance,
(C) Flexibility,
(D) Power consumption,
(E) Speed regulation,
(F) Cost.

Reliability is of first importance because the furnace is so completely dependent on the skip hoist for material practically every minute of the day. An outage of the hoist of even a half-hour may be an extremely serious matter if it should occur when the furnace is working down rapidly.

The second important factor mentioned was maintenance. While constant supervision is good insurance against prolonged shut-downs, the actual replacement of parts and readjustment of devices should only be necessary at infrequent intervals. This requires simplicity in the control, and rugged, conservatively rated, and smooth operating equipment.

The third point is the question of flexibility. The speed range should be flexible to permit changing the high speed and the dumping speed. The control scheme should, as far as possible, permit of adjustment in a simple and effective manner without too much compromising.

†Presented before Chicago District Section A. I. & S. E. E. January, 1931.

*Industrial Engineering Department, General Electric Company, Schenectady, N. Y.

The fourth consideration mentioned is power consumption. Power is a commodity and it costs money to produce. Often the saving in this item alone is sufficient to cover carrying charges on more expensive equipment. And there is a lot of possibilities in this item when it is remembered that the power consumption per year is over 700,000 KW. Hrs. which, of course, depends greatly on the type of control used and the amount of material handled. In making comparisons of power consumption, care must be taken to be certain that the same operating conditions exist in each case.

Speed regulation of the hoist is next in importance. A control that will maintain uniform operating speeds regardless of the load will very materially increase the capacity of the hoist as brought out in an earlier part of this paper.

First cost is placed last, for while the expenditure for an equipment must be justified, there is so much dependent on the successful performance of the hoist at all times that it should be considered only from a relative standpoint.

(4) Discussion of Operating Characteristics of the Above Types of Drive.

With these points in mind, the operating characteristics of the different types of drives outlined will be considered.

Alternating Current Motor Drive

The squirrel cage motor has worked out the best of the alternating current type of motor largely because of its reliability as a rotating machine without commutator or slip ring and brushes. Since it is necessary to provide a positive slow-down speed, the motor is designed with two separate primary windings super-imposed in the same slots, so that a speed range of 4:1 or 6:1 may be obtained.

The control of this motor necessarily consists of heavy current duty contactors connected in the primary circuit for reversing, accelerating and retardation and includes protection against overload in each winding and against open and reverse phases.

Such a motor is rugged; it provides fairly good speed regulation; it operates with low power consumption; and has a first cost comparable with the single motor D.C. rheostatic drive. Yet the use of the A.C. two-speed motor is open to so many objections that it has not been applied very extensively. First of all, it is a difficult motor to repair in case of coil failure, because of the two windings in the same slots. It is also difficult to keep the motor cool on account of the necessity of having a high resistance rotor to give high starting torque. This means large constant losses at full speed, in addition to the losses during acceleration, all of which, must be dissipated within the machine. Therefore, when the hoist is worked hard, the motor generally overheats. Also such a motor is very sensitive to voltage fluctuations—the torque varying as the square of the voltage, that is, a voltage dip of 10% below normal reduces the torque 19%. This means good voltage regulation is very necessary at the motor terminals.

A combination slip ring and squirrel cage construction will get away from over-heating. The slip ring section of the motor is used for the normal running speed of the hoist thus accelerating losses are dissipated in a resistor external to the motor, and the squirrel cage part of the machine is used only for the slow speed operation. However, such a motor has so much flywheel effect that a disproportionate amount of its available torque must be used to get it up to speed and for retardation.

Another objection to the A.C. two-speed motor is its inflexibility; it has two very definite speeds which cannot be changed. Also it is a low power factor machine. Furthermore, when used to feed a furnace with a Neeland type top, it is a very difficult matter to keep the bucket from swaying, during retardation. This must be avoided to properly seat the bucket on the ring at the furnace top.

Single Motor D.C. Drive

The single motor D.C. drive with rheostatic control has, no doubt, been the most extensively used of all types of drives and probably will continue to find usage in the future with small size stacks. It has been customary to use compound wound motors in order to obtain maximum torque per ampere at start. This is a very desirable characteristic, because the rope pull at start is a maximum, due to the high starting friction and, in the case of a balance type of skip, to the reduced overhauling effect of the up ended bucket in the dumping knuckle. Since the series field must be wound cumulative to obtain the above characteristics, the speed of the hoist will vary considerable with the load, unless it is possible to short circuit the series winding after the hoist has accelerated. It is practical to build special motors so that this can be done, but if mill type motors are to be applied, the space factor is not sufficient, in many cases, to permit winding on enough series turns to do much good. In this case, a shunt wound mill type motor is a very good application, if it is designed with partial voltage field, so that when "forced" by applying full voltage during starting, the resultant field flux will be comparable to that obtained from a compound wound, or even a series wound motor. Such a motor will have the additional advantage of fairly constant full speed regulation over the load range and does not lose torque due to armature reaction during the current peaks of acceleration and retardation.

For slow-speed hoists that do not require a very broad range between full speed and the dumping speed, a single motor drive with rheostatic control makes a simple mechanical and electrical equipment and has a low first cost. However, for skip speeds much above 300 F.P.M., the dumping speed is difficult to obtain without the necessity of being extremely wasteful of current through the armature shunt resistors.

This type of drive though is inflexible; it requires heavy current duty contactors; power consumption per ton of material is high and increases as the skip speed increases; and its time efficiency is poor, largely on account of the great speed variation with load during the operation at the dumping speed. With control that is now available, however, the time efficiency is greatly improved over that obtained with the early scheme of control. This is done by the use of load discriminating relays which select the amount of armature shunting resistance to be used during the dumping speed.

The points mentioned above will be somewhat clear perhaps, by referring to Figs. 1 and 2. In Fig.

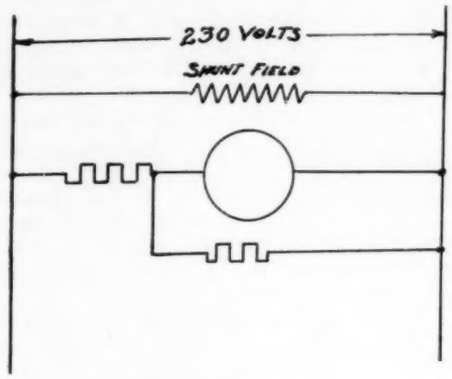


FIG 1

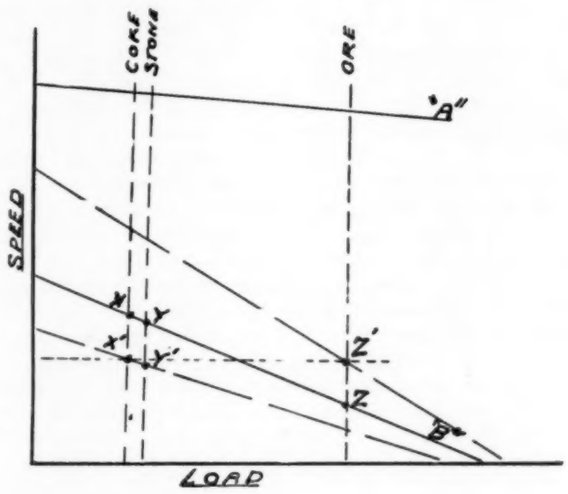


FIG 2

1, a simple shunt wound D.C. motor is shown which has a speed load regulation curve, "A", with full voltage applied to the armature. To slow such a motor down, it is necessary to apply reduced voltage to the armature in proportion to the amount of speed reduction desired. The method commonly used to obtain the voltage reduction, is to use series and shunt resistance in the armature circuit. The voltage drop in the series resistance is then proportional to the sum of the currents flowing through the armature and through the shunt resistance. The slope, then, of curve "B" depends on the ratio of the current flowing through these two circuits so that the speed change with load will decrease as the current through the armature shunt resistor is increased. Thus, since good speed regulation during slow-down can only be accomplished by being extremely wasteful of current, a compromise is usually attempted so that a bucket with iron ore will run at some point "Z" below the average desired, and coke and stone loads at speeds above the average, such as points "X" and "Y". With load discriminating relays, the amount of armature shunt resistance can be selected so that the point "Z" will be raised to X′ and Y′ and points "X" and "Y" lowered to Z′ and Y′.

D.C. Adjustable Speed Motor

When the skip speed begins to get much above 250 F.P.M., the adjustable speed motor makes a very good application for a single motor drive. Such a motor has excellent starting torque per ampere characteristics, and providing the skip speed is not too high, the slow speed regulation is better than can be obtained from a single-speed motor. Also on the basis of the same skip speed, the power consumption is less than the single-speed motor because it is not necessary to waste so much current through the armature shunt resistance to get the slow-down speed.

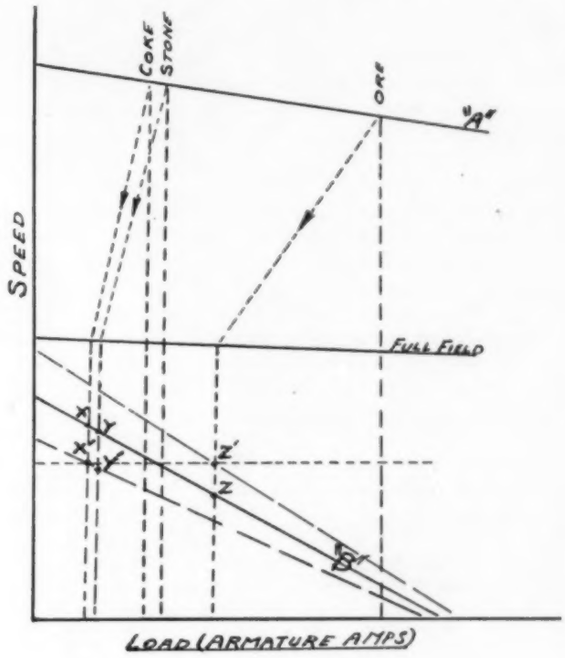


FIG 3

By referring to Fig. 3, an adjustable speed motor will have a speed load regulation curve at weak field as shown by curve "A". Now then, by strengthening the field so that the speed will be reduced about one-half, the armature current, will, for the same torque load, be reduced 50%. Thus, it will be noted that to obtain a given speed reduction, it is not necessary to reduce the armature voltage to the extent that is required with a single speed motor, and also that better speed regulation can be obtained for the same expenditure of current through the armature shunt resistance.

Such a motor also provides more flexibility as its speed can be easily changed by field control from basic speed to its maximum operating speed. However, it is a much more expensive motor to build than a single-speed type, but the control is somewhat simpler.

Double Motor Drive With Rheostatic Control

Two compound wound motors, usually mill type, are often used to drive the hoist with the control arranged to give series parallel operation. This gives a positive slow-down to half speed and therefore, can be used to operate fairly high speed hoists successfully. Armature shunting must, of course, be

resorted to, to obtain a sufficiently low speed for dumping purposes.

This type of control requires a large number of heavy current devices; it is complicated and inflexible. It must be carefully laid out, particularly if series wound brakes are used, to avoid difficulty due to the brakes setting during the transition from parallel to series operation.

A hoist of this sort has a considerable variation in its operating time cycle because, due to the necessity of using compound wound motors to make them divide the load, the full speed will change as much as 25% between coke and ore loads. This added to the variation in the dumping speed, results in poor time efficiency. While such an electrical equipment makes a complicated set-up, it has the advantage over the adjustable speed, single-motor drive in that in case of one motor failing, it is generally possible to continue operation at reduced capacity until the motor is replaced. There is not much flexibility otherwise with this type of drive.

Power consumption on the basis of per ton material handled is considerably lower than when a single-speed motor is used. Also when compared with an adjustable speed motor, a slight saving will be obtained because the flywheel effect of the single motor armature is more than that of a two-motor combination. However, when series wound brakes are used with the two-motor combination, the power consumption will be greater than if shunt wound brakes are used, due to the necessity of providing a by-pass circuit to prevent the brakes setting on transition back from parallel to series operation of the motors.

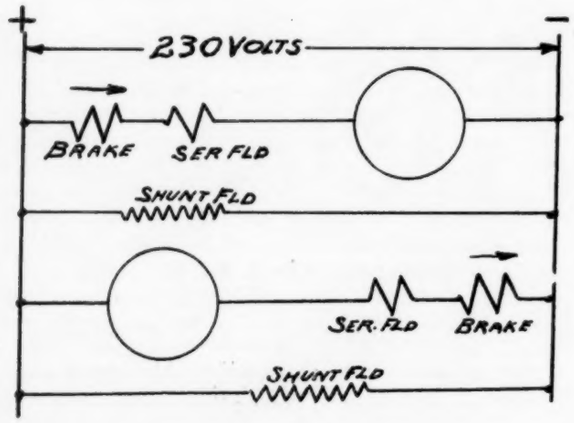


FIG 4

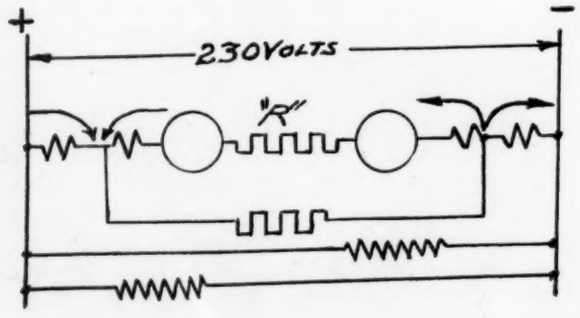


FIG 5

This will be more readily apparent by referring to Figs. 4 and 5. When the two motors are operating in parallel with full voltage (Fig. 4), the counter EMF will be from 85% to 95% of line voltage. Now, when the two motors are switched back to series operation, there will be from 170% to 190% line voltage tending to pump current back, which will be limited by the series resistance "R". To prevent the brake setting, a by-pass circuit is provided around the motor armature of sufficient capacity to absorb this regenerated current, in addition to the line current that must be maintained through the brake coils.

A preferable method of slowing down, is to first reduce the armature voltages to a value where the sum will be somewhat less than the line voltage before switching back to series operation.

First cost of this type of drive is very much higher than when single-speed motor operation is used as the motors and control are a lot more expensive as well as the mechanical set-up.

In general rheostatic control is complicated; it is inflexible; it requires a large number of heavy current duty devices; it can be unduly wasteful of power through misadjustment; and it is hard on the mechanical equipment. This latter point is not generally appreciated, but the sudden torque changes which occur during acceleration and retardation, as the contactors close and open have just the same effect as a series of hammer blows would have on the equipment.

Single Direct Current Motor Drive with Ward-Leonard Control

In any electrical system, the bulk of the maintenance and trouble occurs in the control, and therefore, the simpler this can be made, the greater will be the reliability. To accomplish this, there has been a very definite trend, during the past few years toward the use of Ward-Leonard control, particularly for skips running 400 F.P.M. and up. This type of control seems to fulfill all the requirements of this application to a greater extent than any other type of control. It is first of all extremely simple and has but few control devices, which in the main carries but 15 or 20 amperes. This simplicity, and the smaller values of current, results in greater continuity of service. Reports on equipments that were installed in 1925 state that the expense of maintenance to date has been negligible, and in the main has only required the replacement of a few contact tips worth about 15 cents a piece.

A second factor favoring this type of control is its flexibility of speed range. While the machines are ordinarily designed for a certain nominal voltage to give rated speeds, in most cases this can be increased at least 20 to 25%, and in addition, a further speed increase of at least 10% can be obtained by field weakening, and not only can the high speed be changed, but also the slow running speed. This is quite important because, as previously stated, the

maximum output of a given hoist can be very materially increased by keeping the dumping speed as high as practicable. A well designed control has provision to conveniently adjust both the high and slow speeds over a certain range by means of either switches or field rheostats. Other speed adjustments can be easily made by simply changing field resistor tap connections.

A third factor is the constant speed regulation that is possible with the Ward-Leonard system. With rheostatic control, a six second variation in operating time between dumping an ore load and coke load is not at all uncommon. On the other hand, a well designed Ward-Leonard control system will handle either a coke or iron ore load with practically no difference in time. This means that with a given hoist, greater capacity can be obtained.

The time to get a hoist into service after it is installed is also important. Here again the Ward-Leonard system has the advantage over rheostatic control, because of the simplicity of the control adjustment, whereas, rheostatic control generally requires adjustment of the armature series and shunt resistors, as well as the various control relays.

With rheostatic control, means are usually provided to make certain that the brake will only release when current is flowing in the motor armature so that sufficient torque will be developed to hold the load. This is accomplished by using either a shunt wound brake operated from a series relay connected in the armature circuit of the motor, or by a series wound brake. Both of these methods have some complication—that is, to provide the necessary holding circuit in the first case after the brake has released, or when a series brake is used, it is necessary to prevent it setting on light load or due to pump back current during retardation.

With Ward-Leonard control on the other hand, these precautions of having armature current flowing before releasing the brake is not necessary, as the inherent characteristic of this control will prevent a bucket running away as long as the motor and generator are tied together, and there is field on the motor. As a matter of fact, the brake can be completely released and the hoist will barely creep. Also since the hoist is practically stopped normally by regenerative braking, the wear on the mechanical brake is negligible.

It is often the case, that D.C. systems are overloaded, making it necessary to install additional converting equipment if a D.C. drive is to be used. This becomes unnecessary when the Ward-Leonard system is used, as the high voltage A.C. can be utilized. Furthermore, the power peaks on the distribution system are but slightly higher during acceleration than the full hoisting power required, because the peak accelerating current occurs before the generator has built up its voltage to the normal operating value.

The absence of sudden torque changes with Ward-Leonard control certainly means that the mechanical equipment will require less maintenance in a given time.

Figures on power consumption from a comparison between a 200 HP. A.C. multi-speed squirrel cage motor drive and a Ward-Leonard drive using two 150 HP. motors showed on the basis of KW. hours per ton material handled that the A.C. hoist required .637 KW. hours, while the Ward-Leonard operated hoist required .554 KW. hours, or a saving of 13%. The comparison of D.C. rheostatic control and Ward-Leonard control should show even a better saving than the above figures because of the greater rheostat losses. It will be very interesting to know how this data compares with the results from Ward-Leonard hoists that have been recently put into operation in this vicinity. The reason Ward-Leonard control shows up so well on power consumption even with its lower overall efficiency is that the power input is proportional to the hoisting speed and that the accelerating losses are low because a considerable amount of the power put into the equipment during acceleration is pumped back during retardation.

In applying Ward-Leonard control, it must be assumed that a generator having a rating equivalent to the hoist motor will give successful operation. A Ward-Leonard system must be carefully designed in all its component parts, and for this reason, it is preferable that one electrical manufacturer have the control of the complete design, and thus determine the design of the generator, the motor driving it, the hoist motor, and the control, so that all will work together to the best advantage. It is essential that the generator be designed with attention given to commutation characteristics; to stability of voltage corresponding to the various speeds of the hoist; to have the proper time constant in building up voltage; and to voltage regulation. The motor driving set must have close speed regulation, and a sufficiently high pull-out torque to carry over the accelerating peaks, even during a voltage dip of at least 15%. The hoist operating motor must likewise be designed with proper commutation and stability characteristics. In this respect, open mill type motors are usually very successful when properly applied.

The control must be laid out to work the generator and hoist motor to the best advantage, and furthermore, it is important to give consideration to the type of top that will be used with the furnace, in designing the control. For instance, a Neeland top requires that the speed be slow until the bucket is picked up and latched, and then the acceleration to full speed must be smooth to prevent the bucket swaying. Also, the retardation must likewise be smooth for the same reason. On the other hand, the hoist control for a McKee type of top should be arranged so that the bucket will be righted without too much shock and then the acceleration may be as rapid as commutation will permit.

The motor driving the set may be either a synchronous type or a squirrel cage induction type. The former has three main advantages and that is—constant speed of the set, power factor correction, and is less sensitive to voltage dips. In other words, the maximum torque of a squirrel cage motor varies as the square of the voltage, whereas, the synchronous motor torque varies directly as the voltage. Full voltage starting may be used with either motor, if the power system has sufficient capacity to withstand this peak, and this is usually the case. The synchronous motor drive, however, has a slight additional complication over the squirrel cage motor in that control of its field must be provided.

Two-Motor Drive With Ward-Leonard Control

Ward-Leonard control may be used with either a single hoist motor or a two-motor drive. With a two-motor drive, the control is often arranged so that one motor can be readily cut out of service. The motors are usually operated in series and accordingly if the equipment must carry full load under this condition, of single-motor operation, it is necessary to design the generator for double current duty.

Ward-Leonard control is, therefore, an excellent application for a blast furnace skip hoist from an engineering standpoint; it is reliable, requires very little maintenance; it is extremely flexible; and has low power consumption and high time efficiency.

The principal objection is the matter of first cost and spare parts. The first cost is usually from 150 to 200% of the cost of a rheostatic operated drive. However, it must be borne in mind that a complete blast furnace represents a capital investment in excess of $1,000,000, and it is completely dependent on the skip hoist for all the raw material. This material, as pointed out previously, must be delivered at a fairly uniform rate, day in and day out, and any prolonged shut-down is extremely serious from a loss of revenue standpoint, as well as due to the difficulty of getting back into operation.

The spare part situation is not always very formidable if a study is made of the equipment in a mill. It often happens that not only the hoist motors can be duplicates of other motors about the plant, but also the motor driving the set and possibly the generator itself can be duplicated after a careful check is made of its characteristics.

(5) General Conclusion.

An analysis of this discussion of the characteristics of each of the different types of electrical equipment that may be selected, will result in the following general conclusions. These, of course, must be modified by local conditions.

For skip speeds which are not over about 350 F.P.M., rheostatic control is justified. The question then is whether a single motor drive or two-motor drive should be used. A single-speed, one-motor drive makes a very successful installation when the operating speed is under about 300 F.P.M. However, when the speed gets up above 250 F.P.M., the adjustable speed motor, 2:1 and 3:1 speed range will begin to show up to advantage and will give very good performance up to speeds in the neighborhood of 400 F.P.M.

A two-motor drive also enters the picture at around 250 F.P.M. and finds some justification over the adjustable speed motor drive in the possibility of single motor operation in case of one motor failing.

When the skip speed approaches 400 F.P.M., it means that greater continuity of operation is necessary; that the hoist will work at a greater rate; in other words, it will make a greater number of starts and stops per day. Also the higher speed means that the percentage of full speed operating time in the cycle is less. Thus the higher the skip speed, the greater becomes the importance of reliability, flexibility, power consumption and time efficiency. These requirements are more completely met with Ward-Leonard control than with rheostatic control. The choice of single motor or two-motor drive seems to favor the latter in most cases, because mill type motors can be applied, unless the hoist is of unusual capacity—and on acount of the greater reliability. If the motors are conservatively selected so that one will carry on with load of about 75% of normal, the chances of motor failure are greatly reduced when both motors are operating.

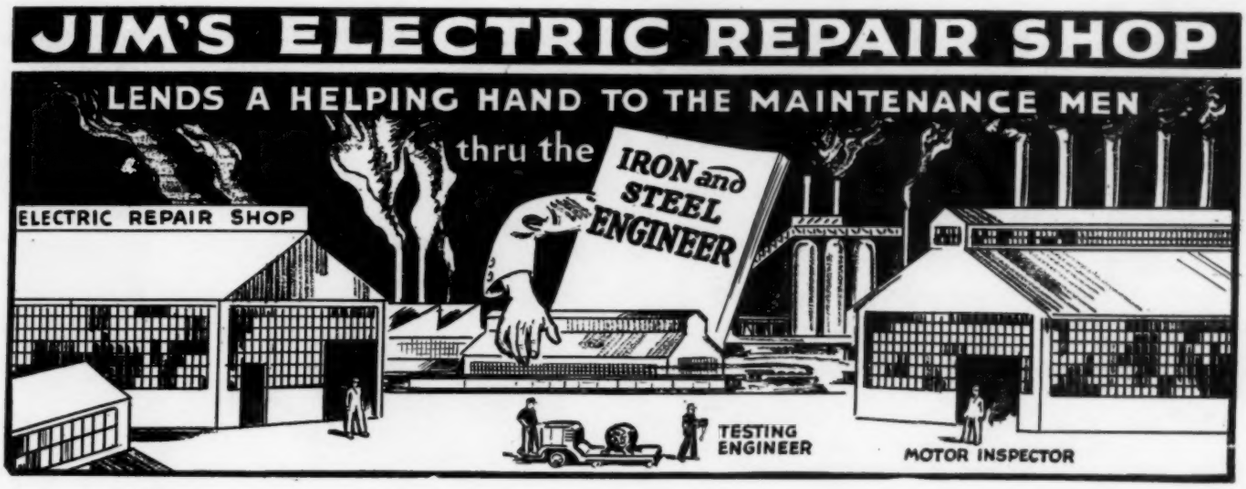
For hoists which use a suspended type of bucket, the smooth acceleration and retardation that is obtained with the Ward-Leonard control practically eliminates bucket swaying.

Discussion

A question was raised in regard to the operation of the discriminating relays used with rheostatic control to obtain approximately constant dumping speeds for coke and ore loads. It was pointed out that these relays are arranged to function on armature current, which is a measure of the load when steady conditions are obtained after acceleration. Circuits are then set up so that when the hoist is slowed down, the amount of armature shunting resistance is selected on the basis of the load. Thus with a coke or stone load, a low value of resistance is selected, and a high value when the load is ore.

The use of a flywheel on the motor generator set furnishing power to a Ward-Leonard control was raised. In answering this question, it was stated that no particular benefit would result from the use of a flywheel as the power peaks on a Ward-Leonard system are but very little higher than the power required to hoist full load because the peak accelerating current occurs before the generator has built up its voltage to normal. Therefore the stored energy in the flywheel cannot be used to any advantage.

The comparative cost of a Ward-Leonard system with rheostatic control drive was desired. The difference in cost, it was pointed out, varied greatly and depended on the particular types of equipment that would be considered, such as single motor drives and two-motor drives, or whether the comparison would be with a single-speed rheostatic controlled motor or an adjustable speed motor. As a very rough approximation, a comparison of the hoist electrical equipment on the basis of two-motor drives with series parallel control and a similar drive with Ward-Leonard control would show that the latter control would cost about 150% of the rheostatic control. Mr. Hall, however, stated that in his opinion this comparison was high, particularly when all of the factors were considered such as converting equipment, etc.



REBUILDING COMMUTATORS

Since a Commutator failure invariably means the loss of the armature winding, every Maintenance man should find it economical to learn the "Nine Essential Features to Rebuilding a Commutator."

These Nine Essential Features to Rebuilding a Commutator are as follows:

DESIGN—"Vee" Bound Construction. When drawn up tight, pressure is uniformly distributed. This makes a good mechanical job.

COPPER BARS—Hard Drawn Copper. High conductivity (98%). Mechanically strong. Straightened, Burrs removed and bright dipped.

MICA SEGMENTS—Selected Raw Mica. Free from impurities. Sheets properly bonded. Seasoned under pressure. Thickness held within .0005.

MICA EXTENSION — Mica Extension 1/16 Back of Commutator neck and 1/32" at fit on bushing. This improves insulation and reduces short-circuits.

MACHINING—Corners on Face Rounded, necks correctly slotted, "Vees" carefully machined and all burrs removed, using special designed tools.

BAKING—Assembled segments baked at 125° to 150° Cent. Automatic control of heat. This seasoning produces a dependable commutator.

TESTING—For Short-circuits between bars-500 volts. Assembled commutators are given 4000 Volts test to ground.

INSPECTION—Correct number of bars, radial alignment, machining of "Vees," ove rall dimensions, quality and finish.

IMPORTANT POINTS IN REBUILDING

(1) Keep all parts free from dust and moisture.

(2) Assemble while cold and take up slack with nut or bolts.

(3) Remove temporary steel bands. (Cracks between bars may develop. This is not uncommon. Hot pressing closes these and produces a solid and tight commutator).

(4) Heat (Preferably in an oven) to 125° to 150° Cent.

(5) Press while hot at about 20 to 30 Tons.

Eight of these features are important refinements which the manufacturer is careful to incorporate in the replacement parts for your use in rebuilding commutators for machines. The ninth feature lies wholly in the hands of the repair man performing the task.

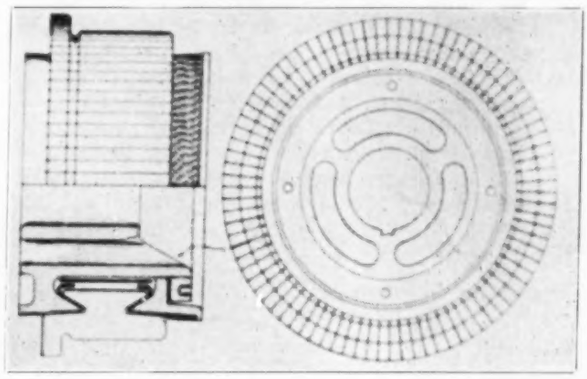


FIG. 1.

Many repair shops tighten their commutators cold without applying an external pressure to the front detachable steel V-ring. They depend upon the ring nut or bolts to provide sufficient pressure to tighten the commutator. On general purpose motors due to space limitation the commutators are designed to be tightened under an external pressure while ring nut or bolts are used to retain the pressure.

Vital Points in Rebuilding Commutators

The following vital points in rebuilding commutators are worthy of your careful consideration:

1—Place the armature in an upright position so you can work to the best advantage.

2—Clean all metal parts thoroughly.

3—Make sure the ring nuts or bolts turn freely and have sufficient threads to tighten the commutator.

4—Clean V's, of assembled segments with sand paper.

5—Check for shorts between bars with 300 volts A. C.

6—Clean the Mica V rings with sand paper.

Caution: Do not touch the Mica V-ring with

the hand where it enters the copper "V" of the assembled segments after cleaning. In doing so, you may deposit steel or dust particles on the ring which may cause a short between bars several years later.

7—Paint the Mica V ring where it enters the copper with a thin coat of shellac.

8—Paint the steel V-ring of the commutator bushing with a thin coat of shellac.

9—Place the rear Mica V-ring over the rear steel V.

10—Place the assembled segments in position.

11—Assemble the front Mica V-ring.

12—Assemble the remaining details of the commutator and tighten the bolts or ring nut by hand.

13—Tape the assembled segments above and below the steel band with friction tape.

14—Cut the steel banding wire with a file.

15—Heat the commutator to a maximum temperature of 150°C or a minimum temperature of 110°C to soften the bond in the mica parts so they will conform to any irregularities of the metal parts.

Caution: Do not heat with a flame direct on the copper bars. To do so will cause what we term a "sick" copper and also soften the copper in the bars. It is preferable to heat the commutator in an oven.

16—Place in a suitable press and apply 15 to 35 tons pressure depending upon the size.

17—Tighten ring nuts or bolts with a wrench to retain the pressure. Do not use bolts or ring nut to tighten commutator.

18—When cold give a 2000 volt ground test and a 440 volt bar to bar test.

19—Test for loose bars.

Commutator Wrench

If the commutator is of the ring nut type a special commutator wrench, having an outer ring and an inner ring should be used. The inner ring has two dowels, 180° apart at one end, which fit into the dowel holes in the ring nut of the commutator. (See Fig. 2).

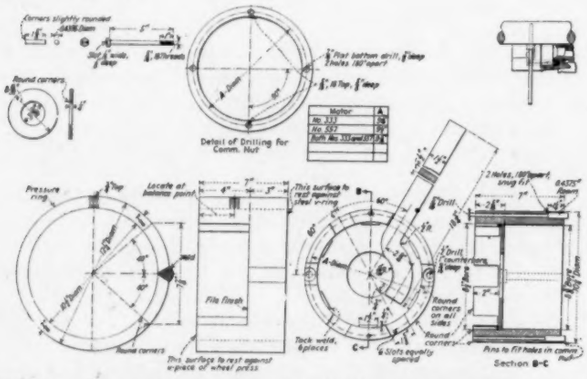


FIG. 2.—Commutator Wrench which can be used in conjunction with a ring press for assembling commutators either while they are on the armature assembly or in a vertical press. At top, pressure ring; at bottom, left, body; at right, handle.

At 90° to the dowels, two holes are drilled thru the ring. These holes are for bolts which are used to fasten the ring to the commutator ring nut. These holes should be large so the dowels and not the bolts will take the wrench pressure. At the other end this ring has notches cut for the handle. (See Fig. 3).

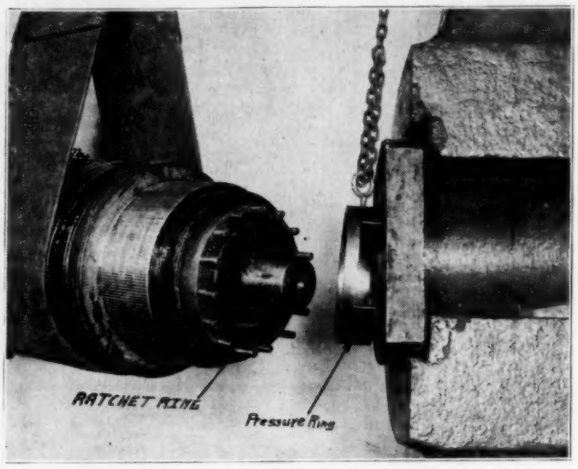


FIG. 3.

The outer ring is used to transmit the pressure from the press to the steel V-ring and fits over the inner ring. The end next to the press has an opening in which the handle may work.

If the commutator is of the bolted construction a socket wrench is used instead of the inner ring, the outer ring still being used to transmit the pressure from the press to the steel V-ring.

Tightening Commutator on Wheel Press

The average repair shop has a wheel press which can be used to good advantage in tightening commutators. In Figure 3 we see the armature supported with the ratchet ring bolted to the ring nut so it will remain in position during the tightening operation and the pressure ring suspended from a chain. In Figure 4 we see the wheel press in operation.

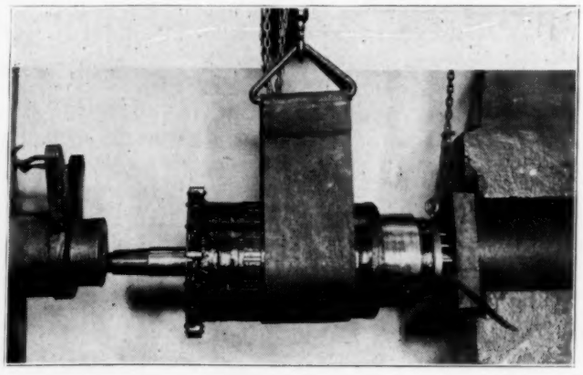


FIG. 4.

When heating the commutator assembly by a torch, if no oven is available, play your flame, preferably on the steel parts of the assembly because they will retain the heat during the tightening operation. If only the copper parts were heated the commutator would cool too rapidly for efficient tightening.

When heating the copper parts it is well to wrap the brush face with tin and play the flame on the tin. If the flame of the torch is to be used on the copper direct, keep the hydrogen part of the flame

from the copper. Sick copper is caused by the hydrogen of the flame penetrating the small pores of the copper and mixing with the free oxygen forming water which due to the heat becomes steam. Since steam is heavier than hydrogen it cannot escape thru the pores which the hydrogen entered. Therefore it expands the copper, and leaves blow-holes or pores.

If you adhere to cleanliness of the parts when assembling, preheat and tighten by applying an external pressure to your assembly, loose commutators will disappear from your list of motor failures.

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V. R. Nelson, Prod. Engr., Gears & Forging, Inc., Cleveland, Ohio.

Items of Interest

PERSONNEL CHANGES

E. C. Stone has been appointed assistant to the senior vice president of the Philadelphia Company and subsidiary companies. Mr. Stone, who organized the system operating department of the local light company in 1913, acting as system operator until 1919, is a native of Charlestown, N. H. In 1911 he joined the Allegheny County Light Company, which two years later become the Duquesne Light Company.

Mr. Stone acted as system operator until 1919, at which time he was promoted to technical assistant to the general manager. He became planning engineer in 1922, in which position he organized and developed the planning division, a new activity in the engineering department, the function of which was to plan systematically and economically the development of the power system to meet the constantly increasing demands which were made on it by virtue of the growth of the company's business. He was made system development manager on January 1, 1927.

Mr. Stone is a member of the Association of Iron and Steel Electrical Engineers and the membership offer their congratulations and best wishes in his new position.

J. M. Hughes, who has been identified with the Sharon Steel Hoop Company, Sharon, Pa., for many years and as superintendent at the Lowellville plant at Lowellville, Ohio, for the past few years, has been appointed general superintendent succeeding W. B. Caldwell, who has resigned. E. E. Reagel, assistant superintendent of strip mills of the Sharon company, has been appointed superintendent, replacing George W. Pfeffer, who has resigned after a connection of 11 years with the company.

Appointment of D. C. Prince as Engineer of the switchgear department of the General Electric Company at Philadelphia, is announced by Neil Currie, Jr., Manager of the plant. The appointment, which was made effective as of February 12, includes supervision of switchgear research activities at Schenectady.

G. T. Snyder, formerly Chief Engineer of National Tube Company at Lorain, Ohio, is now associated with Mr. P. C. Patterson, Vice President, National Tube Company with offices at Frick Building, Pittsburgh, Pa.

E. S. Simkins, well known throughout the Iron and Steel Industry is now associated with the Anaconda Wire and Cable Company in the Chicago district.

Eric Zachau has been appointed Vice President and General Manager of the Michigan Welding Supply Corporation, Muskegon, Michigan. This company has been formed to manufacture a line of arc welding supplies.

E. F. W. Salisbury, formerly with the Cable Accessories Corporation of Pittsburgh, Pa., is now connected with the Anaconda Wire and Cable Company, Cable Accessories Department at Hastings-on-Hudson, N. Y.

Joseph McKinley has been appointed Acting Vice President in charge of sales and service of the Duquesne Light Company and the Equitable Gas Company.

Mr. McKinley succeeds George E. Whitwell who has accepted a position with the Philadelphia Electric Company, Philadelphia, as Vice President in charge of sales.

In 1903 he entered the employ of the Allegheny County Light Company, now the Duquesne Light Company. He was the first power salesman for the company and later served as Manager of Power Sales, General Contracting Agent, Manager of the Wholesale Sales and Service Department of the Duquesne Light Company and Equitable Gas Company.

Mr. McKinley is a member of the Association of Iron and Steel Electrical Engineers, and the membership are extending their best wishes for his success in his new connection.

WITH THE MANUFACTURERS

Surface Combustion Corporation of Toledo, Ohio, has installed a Walking Beam Continuous Type Strip Normalizing Oil-Fired Furnace at the Great Lakes Steel Corporation at Detroit, Michigan.

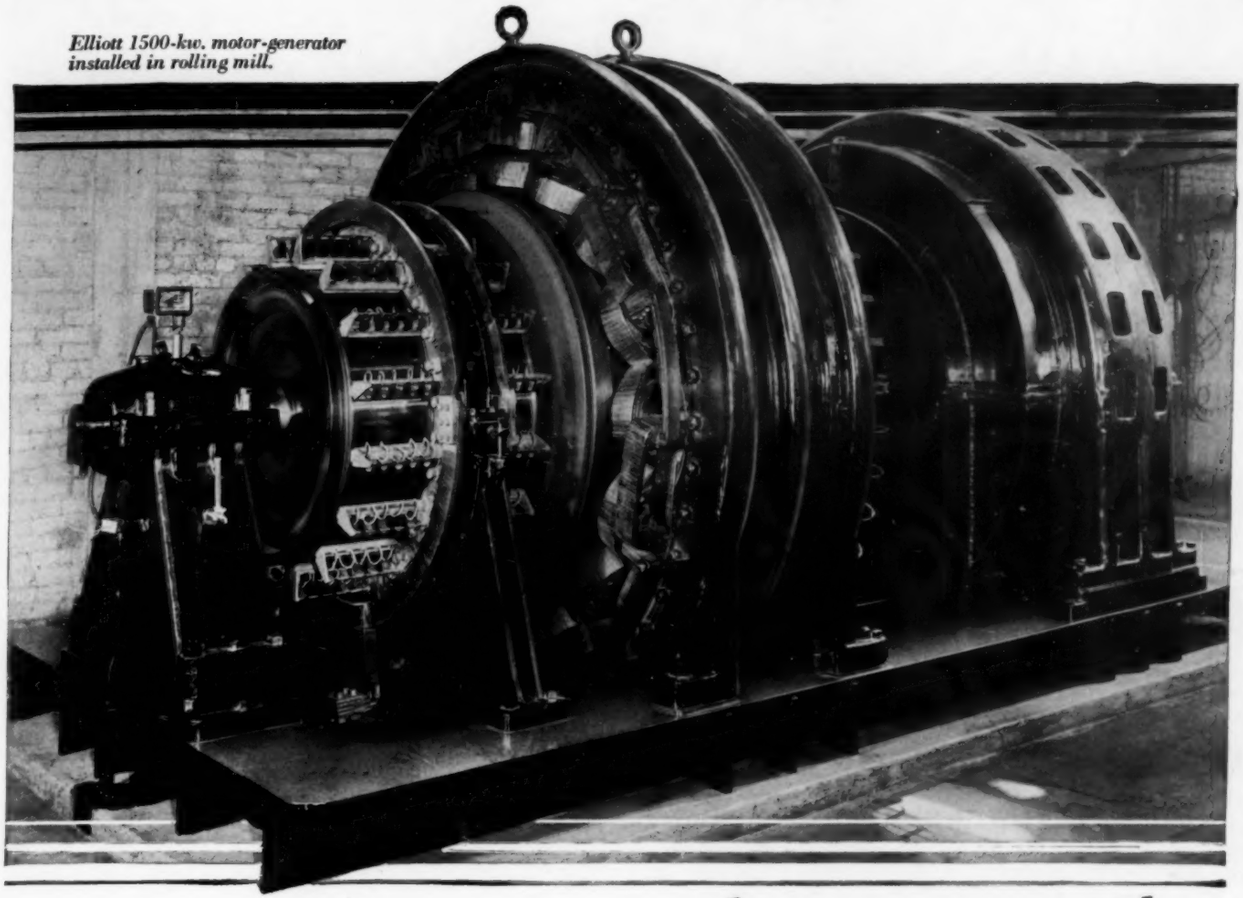
The furnace, which has very recently been put into operation, is designed to normalize steel sheets at approximately 1850°F. Its temperature and mechanism are automatically controlled and an adjustable chain conveyor makes possible a variation of speed through the cooling zone.

The inside width of the furnace is 20 feet. Strips up to 18 feet in length can be normalized in this furnace.

The Allis-Chalmers Manufacturing Company, Pittsburgh Works, Pittsburgh, Pa., are distributing

(Continued on Page 150)

Elliott 1500-kw. motor-generator installed in rolling mill.



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Elliott motor-generator sets with "fully compensated" D. C. generators are built to thrive under the difficult service typical of steel mills. They will handle heavy, rapidly fluctuating loads—with excellent commutation, regulation and efficiency.

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These advantages will be found in all Elliott fully compensated motors, generators and motor-generator sets.

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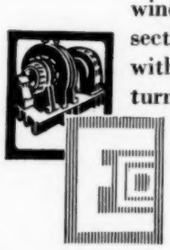

ELLIOTT COMPANY

PITTSBURGH, PA.

Electric Power Department • RIDGWAY, PA.

District Offices in Principal Cities

ELLIOTT *MOTOR-GENERATORS*

(Continued from Page 148)

their new bulletin 3002 on Transformers and their applications. Copies may be obtained on request by interested parties.

The Clark Controller Company, Cleveland, Ohio, manufacturers of electrical and mechanical appartus, owning and operating the Sundh Electric Company, Newark, N. J., manufacturers of electric control apparatus, announce the opening of their district sales and engineering office, 1605 Arcade Building, St. Louis, Mo., effective February 1, 1931.

The Reliance Electric and Engineering Company, Cleveland, Ohio, have developed drip covers applicable to either the alternating or direct-current motors that they manufacture.

The covers are used to protect the motors in bad locations from dripping water, acid or other injurious solutions. In spite of the very high grade insulation used for Reliance Motors, such covers have been found a great help in keeping the motors clean and lowering maintenance costs.

The covers are made of heavy-gauge sheet steel. They are securely bolted to the frames in roof-like fashion so that an opening is provided between motors and cover to permit free circulation.

A 12-page bulletin, recently issued by the Westinghouse Electric and Manufacturing Company, covers Westinghouse 3600 r.p.m. steam turbine-generator units. This publication, which is identified as Circular 1835-A, is replete with illustrations showing the design and construction of all parts of the turbine and generator.

The General Electric Company announces a new heavily coated electrode, designated type R, for quality welding. This particular type of electrode is composed of .13 to .18 carbon steel covered with a heavy coating of cotton braid impregnated with an arc stabilizing flux, and will be available in diameters from 1/8 to 3/8" by 18" length.

Metal deposits of this electrode will have high tensile strength and will produce a homogeneous structure resulting in a ductile weld. This is caused by the fact that, during the arc transference period, the metal is in a protective atmosphere because the electrode itself burns away quicker than the coating and excludes those elements always prevalent in atmosphere which cause some undesirable results when the use of an uncoated rod is used.

Extreme arc stability and high arc voltages permissible from this type of electrode produce an unusual high speed of welding for certain applications.

The new electrode is expected to be of particular value in the field of pipe line welding where speed and ductility are essential requirements.

X-Raying steel, iron and metal up to a thickness of 4½ inches is the service rendered to industry by the newly organized Claud S. Gordon Steel X-Ray Laboratory of Chicago. Patterns, tools, dies, castings, raw material and all shapes and sizes of steel and iron will undergo the microscopic scrutiny of this most powerful of all X-Ray equipment. Inherent defects and bugs will be uncovered just as in the X-Raying of teeth or parts of the human body, a science highly developed in the medical and dental professions.

The United States Navy has awarded to The Automatic Reclosing Circuit Company of Columbus, Ohio contract for building feeder circuit breaker equipment at the Boston Navy Yard Docks, Boston, Mass.

ASSOCIATION NOTES

Mr. C. C. Pecu, General Chairman of the Lubrication Engineering Division, announces one of the most successful Lubrication meetings held February 18, 1931, at Pittsburgh, Pa. The subject discussed was "Devices and Appliances for Steel Mill Roll Neck Lubrication." The following companies presented papers:

Keystone Lubricating Company, Philadelphia, Pa.; The Hodson Corporation, Chicago, Ill.; Lubrication Devices, Incorporated, Battle Creek Mich.; Hills-McCanna Company, Chicago, Ill.; Pennsylvania Lubricating Company, Pittsburgh, Pa.; United American Bosch Corporation, Springfield, Mass.; The Trabon Lubricating Equipment Company, Detroit, Mich.; The Alemite Corporation, Chicago, Ill.

Each paper was based on an actual Steel Mill Installation and the following points as outlined below were covered in each Manufacturer's paper:

Type of Mill and material rolled on mill.

Location of the System; that is, how far is the system from stands?

Are pipes carrying lubricant underground, overhead, etc.?

Are pipes insulated?

How long has system been in operation on this particular installation? It is automatic or manually operated?

How is system operated—by air, water or electricity?

Is the Lubricating System power, independent or is it dependent on the regular plant source of supply?

What arrangements are provided for the quick change of rolls?

Description of the distribution of grease on necks.

Very brief description of control of lubricant at neck.

How is lubricant put into lubricating system from manufacturer's container?

Effect of climatic conditions on lubricating system.

Power savings effected by lubricating system.

Lubricant savings.

Savings in bearings.

Savings in maintenance and upkeep of equipment.

Safety features.

Improvement of product.

Saving in man hours in application of lubricant.

Cleanliness.

Steel Mill Executives, Operating Superintendents and Lubrication Engineers from all of the Steel Centers of the United States, attended this meeting.

OBITUARIES

G. H. Friesel, treasurer, auditor and a director of the United Engineering and Foundry Company, Pittsburgh, Pa., died on February 22, at Baltimore, after an operation. Except for a period of two years, Mr. Friesel has been associated with the United Engineering and Foundry Company since 1905.

John A. Nichols, formerly general superintendent of Corrigan, McKinney Steel Company, Cleveland, Ohio, died on February 12 at his home at La Jolla, Calif. He became connected with the Corrigan, McKinney Company in 1914. He was retired in 1927.